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MANGANESE IN WATERWORKS

BY C. A. H. VON WOLZOGEN KÜHR[1]

The investigation of the part which manganese plays in waterworks was carried out with regard to the Amsterdam dune water. The results which were obtained are of general importance, so that they apply to other kinds of water as well.

In an article written by J. Tillmans,[2] he shows the necessity of removing manganese from drinking water, by stating the bad effects produced by the use of water containing manganese, such as:

1. The forming of dark colored manganese deposit in the pipes, from which all difficulties originate.

2. The forming of brown spots in linen, during the process of washing, as water containing manganese, when mixed with alkali, such as soda and soap, secretes manganic peroxide under the influence of the oxygen of the air.

3. In papermills brown spots are formed on the paper, in breweries the fermentation is disadvantageously affected, while in dye-works the colors become spotty.

The unpleasant consequences of the use of water containing manganese can, according to Tillmans, be effected by even a very small quantity of manganese (Mn), for instance 0.5 mgm. per liter.

[1] Chemist and Bacteriologist, Water Supply Division, Amsterdam, Holland.

[2] Journal für Gasbeleuchtung und Wasserversorgung, LVII Jahrgang, No. 29, p. 713.

As the raw dune water contains manganese, it was therefore necessary to remove it.

THE ORIGIN OF MANGANESE IN DUNE WATER

W. G. N. van der Sleen[3] says that the largest quantity of manganese in dune sand occurs as a corruption of iron-ore, which in the same way as iron dissolves in water containing carbonic acid. Also in the ferrous carbonate concretions of the deeper loam formation in the earth, this writer finds a comparatively large quantity of manganese.

The difficult oxidation of the watery solution of manganous bicarbonate by the oxygen of the air ,was shown to be associated with the hydrogen ion concentration of the solution.

MANGANESE IN CONNECTION WITH MICROBIOLOGICAL PROCESSES

The alterations, which manganese-compounds undergo under the influence of microbes, were studied by M. W. Beijerinck[4] and N. L. Söhngen.[5] The former described a certain group of bacteria and fungi, which occur in the soil and are able to oxidize a manganese compound such as manganous carbonate, into manganese-peroxide. A further examination by Söhngen showed that manganic and manganous compounds can interchange, while he also pointed out that these processes can also take place in the soil.

By former examinations, it is clearly shown that by the biological oxidation process the dissolved manganous compounds can be transformed into undissolved manganic oxide, and that inversely by biological reduction, which always takes place in anaerobic processes, undissolved manganic compounds can pass into dissolved ones. L. Pasteur[6] already observed that the aerobes take the anaerobes in protection, that is to say, the aerobes make the existence of the anaerobes possible.

In this connection Söhngen says, also, that the anaerobic processes take place, not only in anaerobic cultures, but also in aerobic media, after the removal of the oxygen by the growth of microbes, especially in these so-called aerobic cultures, which really only contain on the

[3] Bijdrage tot de kennis der chemische samenstelling van het duinwater in verband met de geomineralogische gesteldheid van den boden, p. 47–49.

[4] Verzamelde geschriften, Dl. V, p. 141.

[5] Centralbl. f. Bakt., 2te Abt., Bd. 40, 1914, p. 545.

[6] Lafar. Handl. d. Techn. Mykologie, 1904–1907, Bd. I, p. 577.

surface an extremely thin layer of liquid containing oxygen. It goes without saying that this principle is not only applicable to soil, but also to water, in which anaerobic and aerobic conditions occur simultaneously, under which circumstances manganese is transformed into manganous carbonate (with superabundance of carbon dioxide in manganous bicarbonate) and manganous sulfate. This is also applicable to the deeper layers of the dunes[7] and also to the mud, settled from the water in the canals of the drainage area and the reservoir of all the dune water, in which the reduction of sulfate very generally occurs as a specific anaerobic process.

IN WHAT FORM IS MANGANESE FOUND IN DUNE WATER?

Originally manganese is dissolved in raw water as manganous sulfate and manganous bicarbonate; to speak more precisely, manganese occurs in ion state. This is not stable, however, in a very dilute watery solution as hydrolysis appears, as shown by the equilibrium equation:

$$MnSO_4 + 2H_2O \rightarrow Mn(OH)_2 + H_2SO_4$$
$$Mn(HCO_3)_2 + 2H_2O \rightarrow Mn(OH)_2 + 2H_2CO_3$$

Manganese would thus, as Tillmans[8] supposes, occur in the water as $Mn(OH)_2$, as by dilution the chemical equilibrium is entirely moved to the right. With ordinary chemical-analytical methods it is impossible to determine in what form manganese occurs in raw water, because the necessary processes easily change its value, so that the original state in which the manganese existed, is lost.

THE RAW DUNE WATER AND THE REMOVAL OF MANGANESE FROM IT

The raw water found in the dunes is led through series of open shallow canals and collected in a general reservoir, out of which the raw water is conducted through a pipe to the purifying-works at Leiduin. The purification of the water is effected here by slow filtration through sand, preceded by a more rapid filtration through coarse gravel.

Although during the passing of the raw water through the canals and

[7] C. A. H. von Wolzogen Kühr. On the occurrence of sulphate reduction in the deeper layers of the earth. Proceedings, Vol. XXV, Nos. 5 and 6, Koninkl. Akad. van Wetenschappen te Amsterdam.

[8] Loc. cit., p. 716.

the reservoir to the purifying station no visible deposit of manganese takes place, the color of the rapid filter gravel, which was originally light colored, is striking in its dark brown tint, by which it shows a great likeness to roasted coffee-beans. Not only the deposit on the gravel, principally consisting of manganese and iron oxide, but also the mud of the rapid filters is dark brown, as it is composed of the same materials.

Sand filters, fed by raw dune-water instead of water from the rapid filters, also prevent manganese from passing. For the present it is sufficient to say that the oxidation of this takes place in the same way as in the rapid filters.

EXAMINATION OF THE COMPOSITION OF THE SEDIMENT OF MANGANESE IN THE RAPID FILTERS

As the rapid filters are so arranged that the oxidation processes of different elements of the raw water play an important part, the oxidation of manganese is very striking. By chemical analysis it appears that the brown indissoluble compounds in the rapid filters consist of ferric and manganic oxide. The structure of the latter was found employing the iodometrical and oxidimetrical method of analysis.

Iodometrical method of analysis

Chiefly this method is based upon the following facts. All manganese oxides can be represented by the formulae $(MnO)_xO_y$, in which x and y represent simple, whole numbers. If one treats manganese oxides with concentrated hydrochloric acid, the reaction takes place according to this scheme:

$$(MnO)_xO_y + 2(x\ y)HCl \rightarrow (x\ y)H_2O + xMnCl_2 + yCl_2 \qquad (I)$$

The coefficient y, which represents the degree of oxidation of manganese oxide, is to be found by stating the quantity of chlorine, which is set free. If however, one adds to manganese oxide dissolved in hydrochloric acid a surplus of alkali and afterwards an agent of oxidation in the form of peroxide of hydrogen or a clear solution of chloride of lime, then manganic dioxide (MnO_2) will appear.[9]

Every manganese oxide can be changed, therefore, by being dissolved in hydrochloric acid, and followed by oxidation in an alkaline

[9] W. Böttger. Qualitative Analyse, 2te Aufl., 1908, p. 213.

medium, into manganic dioxide, represented by the following reaction:

$$(MnO)_xO_3 + x(O) \rightarrow xMnO_2 \qquad (II)$$

The coefficient, x, which represents the quantity of base in manganese oxide, is to be found by stating the quantity of manganic dioxide, which can be done after the equation (I).

One starts with two equal weights of dried sediment of rapid filters and treats the first quantity in the well known apparatus

TABLE 1

Manganese tests by iodometric method

All manganese oxides = $(MnO)_xO_y$, in which x and y are simple, whole numbers.

FOR THE STATING OF X USED 50 MGM. MUD-POWDER⟶MnO_2	FOR THE STATING OF y USED 50 MGM. MUD-POWDER IN ORIGINAL CONDITION	THE VALUES OF x/y IN $(MnO)_xO_y$ FOR THE DIFFERENT MANGANESE OXIDES	THE VALUE OF x/y OBTAINED FROM THE EXAMINED UNKNOWN MANGANESE OXIDE
Used number cubic centimeters 1/100 N thiosulfate solution	Used number cubic centimeters 1/100 N thiosulfate solution	MnO_2 x/y = 1	
1. Anal. 30.2	31.9	Mn_2O_3 x/y = 2	$x/y = \frac{31.2}{31.4}$
2. Anal. 34.8	30.9		= 0.99
3. Anal. 30.0	32.6		
4. Anal. 32.7	30.1	Mn_3O_4 x/y = 3	Rounded off: x/y = 1
Average 31.2	31.4		So the unknown manganese oxide is MnO_2.

of Stortenbeker,[10] and in the same way also the second quantity. In the first test the unknown manganese oxide is converted into manganic dioxide, then one finds from both analyses the proportion, x/y. As this represents for each of the manganese oxides a definite value, from this the composition of the examined manganese oxide follows immediately. Table 1 gives a general view of the result obtained with the sediment, dried at 110°C., containing the brown manganese oxide, by the iodometrical method.

[10] Zeitschr. f. anal. Chem., 29, 1890, p. 272.

Oxidimetric method of analysis

In principle this is quite the same as the iodometrical method. The manganese oxide can be decomposed by oxalic acid by adding sulfuric acid. The surplus of oxalic acid is titrated with potassium permanganate, so that can be stated how much oxalic acid was used by the manganese oxide. If one repeats this determination with the same quantity of this matter, after it has been previously converted into MnO_2, then in the same way as by the iodometrical determination the value of x/y is to be found. The reactions are:

$$(MnO)_xO_y + (COOH)_2 \rightarrow xMnO + 2CO_2 + yH_2O \qquad (I)$$
$$(MnO)_xO_y + x(O) \rightarrow xMnO_2 \qquad (II)$$

in which the coefficients x and y represent, respectively, the quantity of base and the degree of oxidation of the manganese oxide.

The mud of the rapid filters containing manganese, required for the research, is obtained by a violent shaking of washed gravel in wide-mouthed bottles. The mud formed by the rubbing of the gravel stones against each other is then collected and dried. One may use directly the mud of the rapid filters, which, however, is more largely mixed with iron oxide. As it is necessary to remove calcium, which is present, the mud is warmed with diluted acetic acid for the decomposition of calcium carbonate and washed with hot water until no more calcium can be detected. Afterwards the mud is dried and sifted till it becomes a fine powder. The removal of calcium carbonate had the advantage that the mud became richer in manganese oxide.

In table 2 the results obtained by the examination of the mud-powder, dried at 110°C., are shown.

It might be supposed that one had to do with a mixture of manganese oxides, which appear on the analysis as MnO_2. This supposition, however, is for stoichiometrical reasons, which can not be dwelt upon here, untenable.

THE ANALYSIS OF THE COMPONENT PARTS STICKING TO THE GRAVEL

An examination as to the quality of the dark material, which adheres to the gravel of the rapid filters, showed, that besides manganese oxide, iron oxide, silica, calcium and magnesium carbonate and organic matter (detritus and material of microbes), were the component elements. An analysis of the component parts sticking to the gravel, gave the results shown in table 3.

The analysis shows that the greater part of the materials sticking to the gravel of the rapid filter contains manganic peroxide, so that the dark brown color of the gravel is easily understood.

TABLE 2

Manganese tests by oxidimetric method

All manganese oxides = $(MnO)_xO_y$, in which x and y are simple, whole numbers.

FOR THE STATING OF X USED 50 MGM MUD-POWDER→MnO_2	FOR THE STATING OF Y USED 50 MGM MUD-POWDER IN ORIGINAL CONDITION	THE VALUES OF X/Y IN $(MnO)_xO_y$ FOR THE DIFFERENT MANGANESE OXIDES	THE VALUE OF X/Y OBTAINED FROM THE EXAMINATION UNKNOWN MANGANESE OXIDE
Used number cubic centimeters 1/100 N permanganate of potassium	Used number cubic centimeters 1/100 N permanganate potassium	MnO_2 x/y = 1	
1. Anal. 11.5	11.5	Mn_2O_3 x/y = 2	$x/y = \frac{11.34}{11.34} = 1$
2. Anal. 11.2	11.2		
3. Anal. 11.3	11.3		
4. Anal. 11.5	11.3	Mn_3O_4 x/y = 3	So the unknown manganese oxide is MnO_2
5. Anal. 11.2	11.4		
Average 11.34*	11.34		

* This value is not to be compared with that obtained by the iodometrical method, because here a powdered mud with a large mixture of manganese oxide is used.

TABLE 3

Composition of the materials adhering to the gravel

MATERIALS	AMOUNT COMING FROM 10 GRAMS GRAVEL OR 0.150 GRAMS OF ADHERING MATERIAL	EXPRESSED IN PER CENT OF TOTAL QUANTITY OF ADHERING MATERIAL
	grams	
MnO_2	0 050	33.3
Fe_2O_3	0.028	18.7
SiO_2 and elements of ash	0.003	2.0
Ca- and $MgCO_3$	0.027	18.0
Organic matter	0.042	28.0

EXAMINATION OF MUD FROM THE RESERVOIR

As for the question whether the rapid filters form the first stage, where manganese is deposited out of raw water, the answer is in the

negative, since examination proved that the mud from the reservoir as well as that from the canals contained manganic oxide. However, the quantity is small, which seems to be due to the reduction of sulfate in the mud, as noted earlier herein. As is shown there, manganese deposit from the raw water can be dissolved again by the above mentioned process. This is probably one of the reasons why the raw water, notwithstanding its long journey through the canals in the dunes, still contains very little manganese, when it arrives at the purifying station.

The mud consisted of an homogeneous greenish-black mass with a very slight putrid smell. With diluted hydrochloric acid much carbonic acid and hydrogen sulfide developed, the former gas originating from calcium and magnesium carbonate, the latter from iron-sulfide, from which the mud takes its dark color and which is formed by reduction of sulfate. If the water, which the mud contains, is separated from it, we find therein a quantity of manganese not higher than that in raw water, which on an average is nearly 0.3 mgm. per liter.

If the fresh mud is extracted with diluted hydrochloric acid or acetic acid, and then washed well with hot water and afterwards dried, then the powdered mud thus treated, yields when warmed with 10 per cent oxalic acid, notable quantities of dissolved manganese. From the specific effect of oxalic acid upon manganese oxides in general, it may be concluded, that in the mud manganese occurs in the form of oxide.

THE QUALITY OF THE MANGANESE OXIDE IN THE MUD OF THE RESERVOIR

The application of the oxidimetric method, mentioned above should be preceded by the discarding of the easily oxidizable organic matter, as otherwise the titration with permanganate of potassium is impossible. This is effected by prolonged extraction of the mud by dilute hydrochloric acid, by which at the same time calcium was removed, and afterwards in the same way with dilute ammonia solution. By the removal of the above mentioned component parts, the quantity of manganese oxide was increased, so that the analysis can be started with a small quantity. Table 4 gives a review of the results of the analysis.

In the mud, therefore, manganese occurs too in the form of manganese dioxide, so that it is obvious, that this is the general state, in which it settles from raw water. One might think that by a long

continued extraction of the mud with hydrochloric acid and ammonia, it might be possible to discard the lower manganese oxides, which can occur mixed with manganese dioxide. This however is not the case, as by examination I have proved, that Mn_2O_3 as well as Mn_3O_4 in long continued contact with dilute acid solutions and ammonia N/1 to N/2 did not notably dissolve. Also, if through the above mentioned preparatory treatment of the mud a very little of the above mentioned manganese oxides should be dissolved, then enough of the two lower manganese oxides would remain in the mud to be apparent.

TABLE 4

All the manganese oxides = $(MnO)_xO_y$, in which x and y are simple, whole numbers.

FOR THE STATING OF X USED $1\frac{1}{2}$ GRAMS MUD-POWDER $\longrightarrow MnO_2$	FOR THE STATING OF Y USED $1\frac{1}{2}$ GRAMS MUD-POWDER IN ORIGINAL CONDITION	THE VALUES OF X/Y IN $(MnO)_xO_y$ FOR THE DIFFERENT MANGANESE OXIDES	THE VALUE OF X/Y OBTAINED FROM THE EXAMINED UNKNOWN MANGANESE OXIDE
Used number cubic centimeters 1/10 N permanganate of potassium	Used number cubic centimeters 1/10 N permanganate of potassium	MnO_2 x/y = 1	
1. Anal. 1.2	1.2		$x/y = \frac{1.35}{1.30}$
2. Anal. 1.5	1.4	Mn_2O_3 x/y = 2	= 1.03
Average 1.35	1.30	Mn_3O_4 x/y = 3	So the unknown manganese oxide is MnO_2.

If one examines the quantity of deposited manganese oxide in the mud of the reservoir and the different canals, one finds this is very small, as comparatively large quantities of organic matter, iron oxide, silica, calcium and magnesium carbonate (principally the first named) are deposited.

THE AMOUNT OF MANGANESE IN THE MUD OF THE RESERVOIR AND THE CANALS

The compounds of manganese are determined as manganese dioxide. The result of the examination was that the dry mud of the reservoir contained 0.1 per cent, that of the canals 0.05 per cent manganese (Mn). The larger amount of manganese of the mud in

the reservoir of 0.1 per cent is easily understood when we keep in mind that the water of the canals carries the deposited manganese partly as suspension to the reservoir, where it is partly deposited.

Sulfate reduction also occurred in the mud of the canals just as in the mud of the reservoir. That which was said earlier about the dissolving of manganese under the influence of anaerobic processes, as the sulfate reduction, is also entirely applicable to the mud in the canals.

THE CONDITIONS FOR CHEMICAL OXIDATION OF MANGANOUS COMPOUNDS IN DUNE WATER

Of importance is the question whether the oxidation of manganese in dune water can be caused by the oxygen of the air. To examine this, pure manganous carbonate was brought into suspension in dune water (filtered), and in this a strong stream of carbonic dioxide was led for two hours. After filtration of the water, a current of air was led through the clear solution for fifteen hours, for the removal of the surplus of carbon dioxide. By this only a small white deposit was noticed, consisting of manganous carbonate. By a determination of manganese it was proved that the dune water contained, as a result of the above mentioned treatment, 5.9 mgm. manganese (Mn) per liter in solution. Of this manganous carbonate solution, by the addition of indicators, the hydrogen exponent was almost exactly determined. The pH lies between 8.8 and 9.6. The passing of air in this solution for more than twelve hours did not show the slightest oxidation of manganese, otherwise shown by the forming of a brown flaky deposit. A chemical oxidation is for this reason excluded. The hydrogen exponent of the solution was determined, after adding dilute alkali, as well by the effect of air or peroxide of hydrogen. Just a deposit of maganese peroxide was formed. The pH lay between 9.8 and 10.1 and was about 10, as well by the effect of peroxide of hydrogen as by mixing with air, although in the first case the brown coloring by the deposited manganese was formed almost immediately, in the second case within a quarter of an hour. The conclusion from this observation is, that the chemical oxidation of a saturated solution of manganous bicarbonate in dune water needs a larger hydrogen exponent than this solution naturally contains, namely a pH = 10.

The raw dune water has an average pH = 8.1, therefore, considerably less than 10, so that this may be the reason why there is no ques-

tion of a chemical oxidation of dissolved manganous compounds in dune water.

It might be supposed that, in the rapid filters, where the oxidation of ferrous iron into ferric iron can take place, the iron oxide thus formed, perhaps in a catalytic way, can cause the oxidation of dissolved manganese into manganese peroxide. For the examination 10 cc. of the above mentioned solution of manganous bicarbonate was poured into two Erlenmeyer flasks. To one of the latter was added a little solid ferrous sulfate, afterwards both were mixed with air and a few drops of peroxide of hydrogen of 3 per cent were added and slightly warmed. In the flask with ferrous sulfate a brown deposit of iron oxide was formed, which was filtered and washed with hot water; in the other a thin white deposit of manganous carbonate was formed. The two filtered solutions were treated after the method of Marshall, by which the dissolved manganese, by the oxidation of nitrogen acid and ammonium persulfate, and the addition of a little silver nitrate, was changed into permanganate. By colorimetric comparison the color of the permanganate was the same in both cases, so that with the iron no manganese is oxidized. This was moreover proved by dissolving the precipitation of iron in nitrogen acid and also by treating it after the Marshall method, whereby no permanganate was formed.

THE SEARCH FOR MANGANESE MICROBES IN DUNE WATER

From the foregoing it is evident, that as taught by experience, oxidations of dissolved manganese into manganese peroxide take place as well in the rapid filters as in the canals. The solution of this problem is entirely of a microbiological nature as will be seen in what follows. The bacteriological search after the microbes in raw dune water, which cause the manganese oxidation, was carried out after the method of M. W. Beijerinck.

The development of microbes took place on plates of dune water agar, in which freshly precipitated manganous carbonate was evenly suspended, with or without any intentional addition of an organic source of carbon. As a source of nitrogen I used ammonium-sulfate, nitrate and chloride without perceptible difference in the development of the manganese bacteria colonies. For the examination of raw dune water, as well as of the mud of the rapid filters for the presence of manganese microbes, a culture plate of the following composition was used.

Dune water	100	cc.
Agar	2.5	grams
Calcium acetate	1	gram
$(NH_4)_2SO_4$	0.1	gram
K_2HPO_4	0.05	gram
$MnCO_3$	1	gram

With a platinum wire, bent in a right angle, moistened with raw water or a suspension of mud from the rapid filters, inoculation streaks were drawn across the plate. At 25°C. after seven days the streaks, which were first drawn, were visible by the brown color of the developed colonies of the manganese microbes. Not until after two or three weeks were the separate colonies in the last streaks developed, which especially with the use of a magnifying glass were distinctly visible.

By microscopical examination of the colonies under a feeble magnification different colonies could be observed, evidently belonging to different kinds of microbes. Some kinds of colonies showed on their surface definite shape, others simply showed a slight wave, while colonies were found also with rays outside the nearly circular outline. In the middle the colonies were usually dark brown to black, more to the outline somewhat lighter, showing often on the extreme edge a clearly marked yellow or yellow-brown color. If one lets the light fall obliquely upon the colonies, their surface is usually shiny. Figure 1 gives a picture of different manganese-bacteria colonies, to which is added the transverse section. The difference in hue, shown in black, represents the variations, which really are from brown to black. The manganese-bacteria consist of shifting and stationary cells. As a rule they are stationary and occur as mono and diplococci, rods and bacteria united in pairs. The diameter of the monococci was 0.7–1.4 μ. The diplococci and rods were nearly of the same length, namely 2.6–3.3 μ, while the thickness was 0.7–0.8 μ.

Less frequently there appeared on the plate brown colonies, which consisted entirely of shifting bacteria. These were found on a plate of manganous carbonate, infected with mud from the rapid filters and consisted of very small rods of 4 μ in length and 0.3 μ in thickness. I succeeded with the aid of the coloring method of Zettnow, in making of these shifting bacteria a cilia-preparation, though the culture was nearly twenty-one days old, while as a rule for such a coloring only bacteria of a very fresh culture can be used. The shifting bacteria were shown to possess only one polar cilium the length of which was

two or three times that of the rod. Seen through the microscope the bacteria appear as brown to yellow-brown masses, while the separate cells without motion of their own, show as a rule the Brownian motion especially the very small cocci.

The brown manganese oxide, formed by the microbes from the manganous carbonate, may often be seen lying in the cells, an observation upon which more will be said later on.

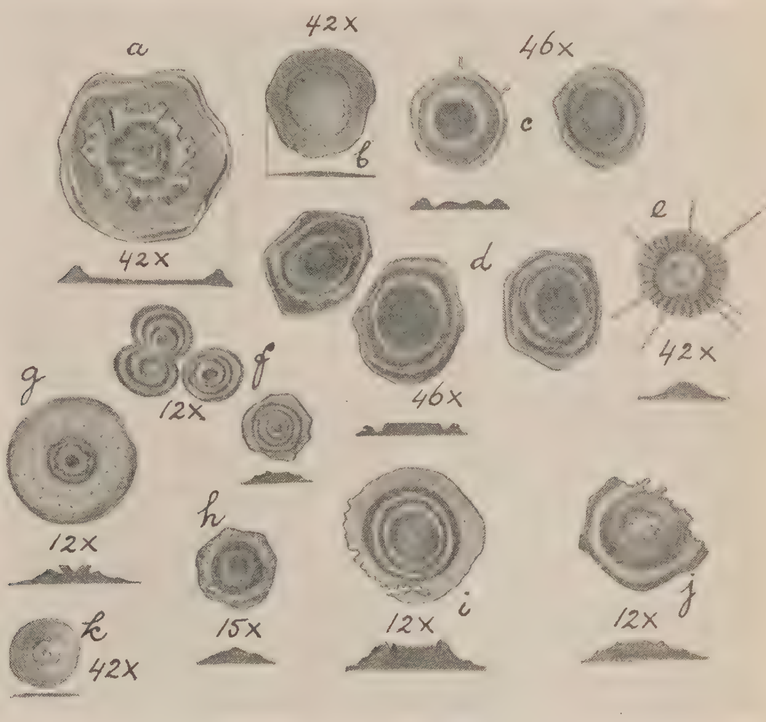

Fig. 1. Manganese Bacteria Colonies

a, *b*, *e*, *h* and *k* are ±3 weeks old. *c* and *d* are ±4 weeks old. *f*, *g*, *i* and *j* are ±6 weeks old.

If one notices the difference in color of the various colonies, which on the same plate can be light to dark brown and even pitch black, this is to be ascribed to the quantity of manganese oxide deposited in the colonies. In the black colonies this quantity is relatively greater than in the lighter colored ones, which is to be attributed to the degree of the manganese oxidation.

Fig. 2. Growth of Manganese Bacteria on a Manganous Carbonate Plate

The dark matter is manganic dioxide (MnO_2)

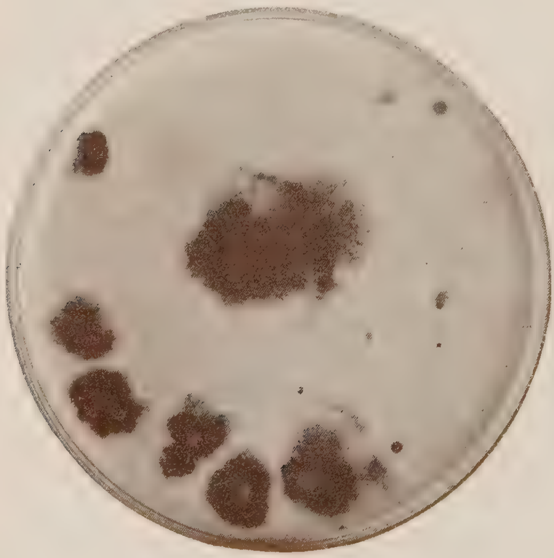

Fig. 3. Growth of a Manganese Fungus on a Manganous Carbonate Plate

The dark matter is manganic dioxide (MnO_2)

Figure 2 shows the growth of the manganese bacteria on a plate of manganous carbonate. In the inoculation streaks the dark manganese oxide is formed.

Besides bacteria, occasionally a fungus was isolated from the mud of the rapid filters, which strongly formed manganese oxide. The composition of the feeding ground was the same as the above mentioned, except that here as source of nitrogen was used 0.1 per cent NH_4NO_3. The growth of the fungus colonies was noticeably quicker than that of the bacteria. After nine days development at 25°C., the diameter of the colonies was nearly 5 mm., after twelve days 18 mm., and after twenty days 28 mm., while the black spots had the same dimensions.

Figure 3 shows how the fungus forms the dark manganese oxide on a manganous carbonate plate.

The attempt to determine the fungus, only led to the determination of the family Pyrenochaeta,[11] as for determining the species the necessary details were wanting. The fungus could easily be held in culture by inoculating, contrary to the manganese bacteria. The latter grew worse and worse, by inoculating for obtaining and maintaining pure cultures while their power of oxidation of manganous carbonate also decreased considerably.

EXAMINATION OF THE COMPOSITION OF THE MANGANESE OXIDE FORMED BY MICROBES

Just the same as in the examination of the composition of the manganese oxide in the mud of the canals and the rapid filters, it is here also necessary to determine the composition of the brown product formed from the manganese carbonate of the culture plate.

That the brown matter is a manganese compound, is proved by the following facts:

1. The decomposition of peroxide of hydrogen, while oxygen is formed.
2. The formation of iodine from potassium iodide in concentrated acid solutions, which colors starch blue.
3. The formation of chlorine from concentrated hydrochloric acid.
4. The specific reduction by oxalic acid, by which discoloration takes place, while at the same time much carbon dioxide is formed.

[11] The determination of the Pyrenochaeta family was achieved by Prof Dr. Joha. Westerdijk, to whom I offer my heartfelt thanks.

5. The solubility with a dark brown color in concentrated sulfuric acid.

The composition of the manganese oxide was found by:

1. Determination of the quantity of manganese (Mn).

2. Determining the above mentioned value of x/y, by the oxidimetric method.

For that purpose the brown matter was collected from the culture plate, rinsed in diluted warm acetic acid, afterwards washed with hot water and dried to a constant weight at 120°C.

The determination of the quantity of manganese as $MnSO_4$[12] resulted in the values 63.0 and 62.7 per cent Mn, which come nearest to the theoretical value of 63.22 per cent Mn and MnO_2.

For x/y, determined by the oxidimetric method, the value of 1.05, was found which belongs to MnO_2. The conclusion is, therefore, that the manganese microbes on the culture plates, just as in the rapid filters, oxidize the manganous compounds into MnO_2. Those microörganisms are usually present in raw dune water, so that the occurrence of MnO_2 in the canals, the reservoir and the rapid filters is easily explained.

THE MICROBIOLOGICAL MANGANESE OXIDATION IN CONNECTION WITH THE HYDROGEN-EXPONENT OF THE FEEDING MEDIUM

We have already seen that the hydrogen exponent plays an important part in the chemical oxidation, namely, that no oxidation takes place, when the pH of the medium is considerably less than 10.

It follows then, that the biological oxidation of the manganese in a medium of which the pH is considerably less than 10, must be possible. In order to show this, a culture plate was made of the following composition:

Dune water	100	cc.
Agar	2.5	grams
$(NH_4)_2SO_4$	0.1	gram
KH_2PO_4	0.05	gram
$Mn(HCO_3)_2$	0.16	gram

For the formation of the feeding medium pure manganous carbonate was suspended in dune water, saturated with carbon dioxide and afterwards filtered. To a warm 2.5 per cent solution of agar in dune water, to which had previously been added the feeding salts and which

[12] F. P. Treadwell. Lehrbuch der analytischen Chemie, II Bd., 1907, p. 96.

was cooled so far, that it was just liquid, so much of the manganous bicarbonate solution was added, that the plate contained 0.05 per cent Mn = 0.16 per cent manganous bicarbonate, in which one may succeed after some practise and without making the culture plate too soft. The quantity of manganese is to be determined by taking out a piece of the agar plate, dissolving this in water and determining the manganese colorimetrically. So in 6 cc. was found 3.01 mgm. Mn, which agrees with a quantity of 0.05 per cent in the culture plate. Using less than this quantity of manganese, the brown coloring of the manganese bacteria colonies may be no longer prominent.

After coagulation of the agar the surface of the plate is carefully dried at about 40°C. Then manganese microbes from the raw water or from the mud of the rapid filters are streaked off on the plate, to be cultivated at 25°C.

In order to examine the exact degree of acidity of the feeding medium, a cylinder of agar was cut out with a corkdrill and the empty space filled up with a solution of blue litmus (obtained by dissolving litmus in thoroughly boiled distilled water), after which the opening was closed with a glass cover in order to prevent the solution from slipping away, when the culture box is held in a vertical position. If now one holds the plate against the light, it is easy to judge the change of color of the litmus. After six hours another cylindrical hole is made in the same way, next to the first one, and filled with the same solution of the litmus. Holding the plate against the light we see that the first litmus cylinder has taken a violet color, whereas the second remains blue.

The difference in color is more or less evident according to the thickness of the layer of agar. The violet color of the litmus solution agrees with a pH of 4 to 5, which produces an acid reaction of the culture plate. After eight days of cultivation, during which the culture dish had been lying upside down in the incubator to prevent the agar layer from drying too quickly, slight brown colonies of manganese bacteria were to be seen in the inoculation streaks on the plate at a fifty-fold magnification. After fully 6 weeks brown spots in the inoculation streaks were visible to the naked eye, consisting of manganic peroxide, as the examination described above proves, while the plate, by repeating the test with the litmus-solution, still gave a decided acid reaction.

This cultivation test showed that the manganese bacteria can develop on a faintly acid medium of manganous bicarbonate. Their

successful growth on ordinary manganous carbonate plates, which gave a slight alkaline reaction by adding calcium acetate and dipotassium phosphate and their capacity of multiplication in the water of rapid filters (pH = 8.1) indeed proves, that their growth is improved by an alkaline reaction of the medium.

Besides being capable of oxidizing dissolved manganese at an alkaline degree, pH = 10, while the oxygen of the air is still inactive, the manganese bacteria can just as well oxidize in an acid medium of a pH 4 to 5, this being explained by the general acceptation that the protoplasm of the living cell reacts alkaline.[13] The oxidation of the manganese into manganic peroxide is supposed to happen in contact with the living protoplasm of the microbe, cell a supposition already made by M. W. Beijerinck[14] when he stated: "dass die Oxydation sicher an die Substanz des Bakterienkörpers gebunden ist."

Using a strong magnification a small quantity of the brown material of the colonies appears to consist of very small light or dark brown lumps. In the lighter ones small micrococci and also short bacteria rods of 0.6 μ thick are visible. When the diaphragm is widely opened, one can distinctly see that the contents of the greater part of cocci and bacteria is brown yellow to brown. As this seems to support the view that the oxidation of the manganese into manganic peroxide in the bacterium cell is promoted by the living protoplasm, in the fungus culture mentioned before, yet lumps of manganic peroxide are to be found outside the mycelium. M. W. Beijerinck[15] also observed that in the fungus Papulospora manganica, manganic peroxide-spheriods lie at a rather great distance from the mycelium threads. No oxidizing matter, diffusing from the mycelium was to be found. Besides, he observed, that there is no question here of an alkaline reaction of the culture plate by the fungus growth. Therefore, he pointed out, there is still but little known about the real mechanism of the oxidation process.

J. Tillmans[16] explains the oxidation of dissolved manganese in slightly acidly reacting water, which cannot be produced by the oxygen of the air, by presupposing that the materials of the filter, such as cokes, stones, sand, etc., can contain alkaline reacting mate-

[13] H. Molish. Mikrochemie der Pflanze, 1913, p. 23.

[14] Verzamelde geschriften, Dl. V, p. 143.

[15] Loc. cit., p. 145.

[16] Loc. cit. p. 720.

rials. In the proximity of these materials the water is supposed to possess a weak alklaine reaction by which manganous hydrate deposits more and more and the oxidation into manganese dioxide proceeds. This purely chemical point of view of Tillmans is not tenable, as first and foremost the influence of the alkaline reacting materials in the water would have to be indicated by the determination of the hydrogen exponent, which has not been proved. We have already found that, even in weakly alkaline reacting water of a pH between 7 and 10, the oxygen of the air by no means produces a manganese oxidation. Secondly, the filling material of the filter comes to a point of being lixiviated, so that a gradual decline should take place in the oxidation of the manganese, which does not occur. Apart from the biological manganese removal from the water, according to Vollmar[17] in Dresden, Tillmans[18] leaves open the possibility that microörganisms coöperate in the oxidation process of the manganese, but this biological oxidation, according to Tillmans, only takes a subordinate place.

It is more rational to replace the chemical explanation of the manganese oxidation by the biochemical point of view, because this quite agrees with the facts.

MANGANESE DIOXIDE RETAINS MANGANOUS COMPOUNDS

A well known property of manganic dioxide is the capacity to retain manganese as manganous compounds from their watery solutions. In many methods of purifying water, one has made use of this knowledge in order to remove manganese from raw water.

As before shown, the manganese bacteria are able to oxidize manganous compounds into manganic dioxide, both in weak acid and weak alkaline solutions, which in its turn absorbs manganous compounds from the water.

Therefore the manganese microbes do not only promote the regeneration of the capacity of manganic dioxide to retain once more manganous compounds by oxidizing them, but they add newly formed manganic dioxide, so that in a normally working rapid filter the manganese removal from raw water can take place without interruption.

When the experimental plant of the rapid filters at Leiduin was

[17] Journal für Gasbeleuchtung und Wasserversorgung, LVII Jahrgang, No. 29, p. 723.

[18] Loc. cit., p. 721.

placed in use in 1907, the filter basins were filled with ordinary new gravel. In the course of time the color of the gravel turned into dark-brown, chiefly by the deposition of manganic dioxide and ferric oxide on the pebbles. In connection with the high quantity of manganic dioxide, which the pebbles retain, one is inclined to think that the filling mass of the filter plays a part in the deposition of manganic dioxide on the pebbles, which by examination proved true.

FRESH GRAVEL RETAINS MANGANOUS COMPOUNDS THE SAME AS MANGANIC DIOXIDE

It soon appeared to me that manganic dioxide was not the only material which retains manganous compounds, e.g. carbon, calcium carbonate and also fresh gravel have the same capacity. This may be shown, by shaking these materials with much diluted manganous solution, which caused the quantity of manganese to decrease. The compound retained by the fresh gravel in a rapid filter is manganese, that indeed appears in solution in raw water, while the everpresent manganese microbes on the surface of the pebbles oxidize the retained manganese into manganic dioxide. The very thin layer of manganic dioxide thus formed retains in its turn dissolved manganese from the surrounding water, which is again oxidized into manganic dioxide. By this uninterrupted and alternating process of retaining and oxidation of the manganese, the manganic dioxide layer grows thicker and thicker, so that in the end it is covered with a dark brown layer. Of course, the thickness of it will be limited, because the layer is worn away by the continually flowing water; especially when the filter is cleaned the gravel is brought in a state of commotion by which the layer gets partly rubbed off from the gravel. The deposition of the mud in the rapid filter contains therefore manganic dioxide.

THE REGENERATION OF MANGANIC DIOXIDE, WHICH IS ALREADY PRESENT, AND THE FORMATION OF FRESH MANGANIC DIOXIDE

Though several materials appear capable of retaining manganese, this quality is particularly important for manganic dioxide, for the following reasons:

1. The regeneration of manganic dioxide, already present, is caused by the oxidation of the retained manganous compounds, which again enables it to retain once more manganous compounds.

2. The oxidation just mentioned continually causes a new formation of manganic dioxide, which, combined with the former quantity

of manganic dioxide, retains ever more manganous compounds. The process of microbiological manganese oxidation leads therefore naturally to the removal of manganese by means of manganic dioxide.

EXPLANATION OF THE PHENOMENA IN THE REMOVAL OF MANGANESE FROM RAW DUNE WATER BY NEW RAPID FILTERS

We have already proved that fresh gravel is capable of retaining dissolved manganese. But the cement walls of the rapid filters, containing calcium carbonate, can as well operate in retaining manganese. The small quantity of manganic dioxide, suspended in the raw water, is able to do this. This manganic dioxide, however small in quantity at first, slowly increases in the working filter and also joins in the absorbing of the dissolved manganese, after the continual regeneration. The same process of the formation of a brown layer over the pebbles takes place also in new rapid filters. Within a few years the gravel turns dark brown.

THE REMOVAL OF THE MANGANESE FROM RAW DUNE WATER BY SANDFILTERS.

When feeding the sandfilters with raw dune water, one is inclined to expect that the sand, like the gravel of the rapid filters, in the course of years would have turned dark brown by the manganese deposition, because the filtered water contains no manganese. By superficial observation however no brown coloring is to be noticed. But when a hole is dug in the sandbed, brown veins are visible in the profile, containing manganic dioxide. In a sandfilter fed with raw water, a process takes place in the sandbed analogous to the process going on in the fresh mass of gravel of a rapid filter. Sand and calcium carbonate which is also present, retain manganese, that is changed into manganic dioxide by oxidation. Gradually there is formed a sufficient quantity of manganic dioxide, by which chiefly manganese from the water is absorbed.

The mass of gravel under the sandfilter also contains brown colored pebbles which color is caused also by manganese dioxide. All this shows that the oxidation of the manganese in a sandfilter takes place throughout the whole depth of the sand and gravel layers of the filter.

THE REASON THE SANDFILTERS ARE NOT CONSPICUOUSLY COLORED BROWN BY THE SETTLED MANGANIC DIOXIDE

Four reasons may be mentioned, which combined explain why the settlement of manganic dioxide does not considerably color the sand of the sandfilters brown, that some years before for a long time were fed with raw water, as it is the case with the gravel of the rapid filters.

1. The periodic removal of the uppermost filter layer, when cleaning the filter, by which a part of the deposited manganic dioxide is also removed.
2. The relatively small quantity of manganese in the raw water amounting to an average of 0.3 mgm. per liter.
3. The low rate of the water passing through the sand bed, being about 10 times slower than in a rapid filter, so that in the same unit of time a quantity of water 10 times smaller comes into touch with a constant quantity of filter material.
4. The whole surface of the sand grains, which is considerably larger than that of the pebbles of gravel in the rapid filter.

THE DISCARDING OF MANGANESE FROM RAPID AND SANDFILTERS TAKES PLACE IN THE SAME WAY

It is evident that the settled manganic dioxide in the sandfilters is formed by manganese microbes, which may be concluded by analogy with the formation of manganic dioxide in the rapid filters. Therefore, the oxidation and removal of the manganese takes place in the same way in both kinds of filters. We do not find any essential difference, but only a gradual one.

In the preceding examination of the processes, going on in the removal of manganese from potable water, only a few questions were answered which form a whole. The manner in which the manganic dioxide retains manganous compounds and by what law it is governed still remain unexplained.

SUMMARY AND CONCLUSIONS

1. While the complete removal of the manganese dissolved in raw dune water takes place in the rapid filters by oxidation into insoluble oxide, by the same process a part of the manganese settles in the open shallow canals of the drainage area. The sulfate reduction generally appearing here probably is one of the causes, why the water does not reach the purifying station free from dissolved manganese.

2. By means of the iodometric and oxidimetric titration methods the deposition of manganese, both in the rapid and in the sandfilters as well as in the mud of the canals, is demonstrated to take the form of manganic dioxide.

3. Manganese microbes appear in raw dune water, which, when cultivated on suitable culture plates, show the capacity to oxidize manganous salts into manganic dioxide.

4. The hydrogen exponent of raw dune water proves to be too low to enable the auto-oxidation of the dissolved manganese. However, the oxidation does take place, due to the ever-present manganese bacteria, which possess the capacity to oxidize manganous salts into manganic dioxide.

5. Fresh gravel has, as manganic dioxide, the same property of retaining dissolved manganous combinations from water. By oxidation, influenced by the manganese microbes, manganic dioxide arises from the manganous compounds, by which the gravel is covered. This thin manganic dioxide layer likewise retains dissolved manganese from the water, which again is oxidized into manganic dioxide. This oxidation causes the manganic oxide already formed to be once more capable of retaining manganous compounds. By this process of regeneration, which at the same time causes the formation of new manganic dioxide, the retention and oxidation of manganous compounds can proceed uninterruptedly. It is characteristic in this process that just manganic dioxide is formed by the oxidation of manganese, which by itself is capable of absorbing dissolved manganese from the water.

6. The removal of manganese in sandfilters, which formerly were with raw dune water, took place exactly in the same way as in the rapid filters. The materials, which at first retained the dissolved manganese, were sand, calcium carbonate and coarse gravel.

7. The whole investigation led to the conclusion, that in the removal of manganese at the waterworks at Leiduin, the bacteria play an essential part.

DISCUSSION

Robert Spurr Weston: The author of this paper has greatly contributed to the fund of information regarding the oxidation of manganese in ground waters. Especially interesting are his methods for determining manganese in its various degrees of oxidation, in

filter beds, pipe deposits, and basin sludges, and his experiments to prove that in the oxidation of manganese the lower bacteria, rather than contact or the higher bacteria (Leptothrix and others of the family), play the important rôle.

The author's experiments indicate that direct oxidation of manganese, as by bubbling air through a manganiferous water, takes place only in highly alkaline waters (pH equals 10) and he ascribes to the manganese bacteria, rather than to catalysis by physical contact, the chief part in oxidation.

It is a little difficult to understand the author's statement that "anäerobic and äerobic conditions occur in the same water at the same time" unless he means conditions like those which occur in deep lakes and ponds. In these waters, reduction may take place in the stagnant zone, while oxidation may be going on in the circulating zone. The same would be true in the lower and upper zones of canals, respectively. Perhaps he means two kinds of water and bacteria in the same body of water, rather than two kinds of active bacteria in the same water.

Sand or gravel filters treating waters containing iron and manganese frequently show distinct zones of discolorization, the upper colored red with iron, the lower brown with manganese.

In the material adhering to the Amsterdam filters, there was 33 per cent of manganese and 28 per cent of organic matter. Manganese found in deposits at Brookline and Newton, Mass., had the compositions given in table 1.

The waters from which these deposits were derived had the characteristics shown in table 2.

It is difficult to go quite so far as the author in giving manganese bacteria sole credit for the oxidation of manganese salts. All will agree that in waters whose pH values range from say 7.5 to 8.5, the accumulated manganic hydrate on the filter sands adsorbs and holds the unoxidized manganese until it becomes slowly oxidized and until the accumulation becomes so great that it sloughs away. However, the author's conclusion regarding bacteria is quite a step away from the older idea of Dunbar and others that bacteria constitute surface, and surface increases adsorption and promotes oxidation by physicochemical action rather than by biolysis. The author's quotation from Beijerink regarding the relatively great distance separating the aggregates of manganese oxide and the body of *Papulospora mangan-*

TABLE 1

Manganese in Deposits, Brookline, Mass.

	TRICKLER DEPOSIT	SEDIMENT FROM TRICKLER EFFLUENT	SEDIMENT FROM FORCE MAIN
	per cent	*per cent*	*per cent*
Silica, SiO_2	19.06	45.29	5.03
Iron oxide, Fe_2O_3	16.84	34.68	16.40
Aluminum oxide, Al_2O_3	0.64	1.20	1.22
Manganic oxide, Mn_3O_4	15.70	3.01	51.95
Calcium oxide, CaO	2.67	0.87	4.24
Loss on ignition	40.44	10.82	17.86

Newton, Mass., Deposit in Wooden Conduit

	NO. 1—NEXT TO WALL	NO. 2—NEXT TO WATER
Silica, SiO_2	7.25	5.4
Iron and aluminum oxides	10.2	85.4
Manganese dioxide	70.+	Trace
Loss on ignition	11.9	4.75

TABLE 2

DETERMINATION	BROOKLINE, WELLS AND GALLERY	NEWTON, WELL AND WOODEN CONDUIT
	p.p.m.	*p.p.m.*
Oxygen consumed	2.05	1.5
Iron, Fe	0.85	0.20
Manganese, Mn	0.20	0.25
Nitrogen as free ammonia	0.040	0.044
Nitrogen as albuminoid ammonia	0.090	0.130
Nitrogen as nitrites	0.000	0.000
Nitrogen as nitrates	0.30	0.12
Hardness	50.0	31.2
Alkalinity	39.0	23.0
Chlorine	8.4	10.0
Residue on evaporation	108.0	80.0
Carbon dioxide	31.8	15.0
pH value		6.5

ica, and also Schwer's[19] experiments at Turnhout, Belgium support Tillman's belief that the rôle of the higher iron bacteria is at least a secondary one. The author's experiments have certainly introduced another group of organisms, and show either that they are the chief oxidizing agents for manganese, or that, when grown in solutions containing manganese and oxygen, manganese salts become a part of their cell substances.

It is a little difficult to imagine that the laws of oxidation apply differently in the case of waters containing manganese than they do in the case of waters containing iron. At Reading, Mass.[20] the writer found that the oxidation of iron failed when water was aerated to such a point that Leptothrix ochraceae would not grow in a trickling filter, and at Lowell Barbour found that manganese could not be removed with iron when aeration was carried so far that the carbon dioxide was reduced to the practicable low limit. These facts do not seem to disprove chemical oxidation of waters having a pH value of less than 10, where the surface area of the precipitated iron in contact with the water under treatment is large.

It must be borne in mind that the time element in the author's experiments on direct oxidation was small compared with that obtaining in a well-ripened filter in practice.

The point is an interesting one, and the writer must now believe that both contact and bacteria are effective agents both for the removal of iron and the removal of manganese, otherwise one could not explain certain stains, due to manganese, on walls and plumbing fixtures where the alkalinity is not high, and where it seems that it would be difficult for oxidizing bacteria to thrive.

John R. Baylis: This excellent article is a valuable contribution to the literature on manganese in water supplies. Troubles from such source are more extended than is generally believed, and the article is not only interesting to those handling water containing manganese, but to every one interested in water treatment. As stated by the author, it has been known that biological growths play an important part in the precipitation and resolution of manganese, but it was not known that the precipitation of manganese, except where special chemical treatment is given, is due almost entirely to certain biological growths. One wonders what would happen if the

[19] Revue'd'Hygiene, xxx, 297, 1908.

[20] Trans. Amer. Soc. C. E., xliv, 151.

water was treated with chlorine to the extent of preventing such growths. It is possible, however, that the presence of an excess of chlorine will cause oxidation of the manganese where it otherwise would not be except by biological growths.

During the first serious manganese occurrence in the Baltimore water supply in 1923, the writer conducted a number of experiments on various means of removing the manganese. In this case biological growths apparently were responsible for the resolution of manganese already precipitated on the bottom of a large storage reservoir and along the walls of a tunnel over 7 miles in length. Part of this work has been published.[21] It was the writer's intention to publish another article giving additional facts brought out by the investigation during subsequent manganese occurrences, but time for writing the article has not been available. Looking over the notes, there seems to be agreement with Kühr's work in so far as the experiments overlap, except in one or two minor points.

It was found that the ortho-tolidin solution used for making residual chlorine tests is the most sensitive test for oxides of manganese containing more oxygen than manganous oxide. This test is sensitive to less than 0.1 part per million of manganese (Mm) existing as manganese dioxide. The addition of an alkali to the Baltimore water containing approximately 1 part per million of manganese gave a slight yellow color when the water was at a pH of 8.0 before the addition of the ortho-tolidin. The color increased as the pH was increased. This, or course, applies to the pH of the water before the addition of the ortho-tolidin.

One might come to the conclusion by reading the article that manganese is not adsorbed by and precipitated with the hydrous oxides of iron. This may be the case when the pH is below 7.0, but when the water is slightly alkaline the amount of manganese occurring ordinarily in water supplies is readily precipitated with the iron. The iron and lime treatment appears to be the most effective means of removing manganese from water. This has been tried out thoroughly at Baltimore, not only in the laboratory but also in the filter plant. One part per million of manganese (Mn) is easily removed with 15 to 20 parts per million of ferrous sulfate ($FeSO_4$, $7H_2O$) and enough lime to give the water a pH of about 8.8 or more alkaline.

The pH of the water apparently has some influence on the removal

[21] Bayli[illegible] R.: Manganese in Baltimore Water Supply. This Journal, vol. 12, no. 2, 211, October, 1924.

of manganese, for one-half of the water at the Baltimore filter plant was treated with lime to a pH of from 8.5 to 9.0 before filtration, in an experiment extending over several weeks, and the filter beds having the alkaline water removed more of the manganese than did the other filters. The water going on to one filter was dosed highly with chlorine for a period of several weeks during one of the manganese occurrences and while this bed showed a better adsorption than did the others the amount removed from the water was still less than 50 per cent of the amount going on to the bed. Draining the filter dry and allowing it to stand in contact with the air for a few hours increased the adsorption about the same as such a procedure did in the beds where no chlorine was added.

Manganese can be removed very easily by chemical treatment of the water, but the writer agrees with Kühr that biological growths play by far the most important part in the oxidation of manganese in most instances. The presence of dissolved oxygen in the water apparently will not cause rapid oxidation of manganous hydroxide when the pH is below about 8.0 or perhaps slightly higher, but there is probably a very slow oxidation below this point which is not rapid enough to cause very much precipitation or adsorption of manganese. Any one troubled with manganese should read this article, for it is a thorough treatment of a subject that has received little attention in this country.

F. E. Hale: The paper on "Manganese in Water Works" by Kühr is a most interesting study from a biological standpoint. Of particular importance is the separation of cocci, bacilli and fungi and the description of method of culture. That bacteria and other organisms may utilize manganese in their life processes has been known for many years. In 1901 D. D. Jackson[22] published a paper from Mt. Prospect Laboratory describing a new species of Crenothrix, C. manganifera, which forms chains of bacteria imbedded in manganese oxide. In describing the three forms:

Crenothrix, kühniana, utilizing iron
Leptothrix, ochracea, utilizing aluminum (suggested name Crenothrix ochracea)
Crenothrix, manganifera, utilizing manganese

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[22] Trans. Amer. Micro. Soc., Vol. 23, pp. 31–39; Jour. Soc. Chem. Ind., May 31, 1902, pp. 681–4.

Jackson states "All three species occur chiefly in ground waters and only grow with rapidity when the dissolved oxygen is lacking, or nearly so, and when the special salts are present which they precipitate. The presence of much organic matter seems to favor the growth, but the two former conditions are absolutely necessary. The absence of light and the presence of carbonic acid in the water are also usual conditions and seem to favor growth." Analyses of the precipitates showed iron, aluminum and manganese oxides predominating in the three respectively and in the waters in which they grew respectively. He also stated that "These salts of iron, aluminum or manganese, combined with organic matter, seem to furnish the food material for the organisms, while the oxides of iron, aluminum or manganese which are precipitated in their gelatinous sheaths are the dross of the operation."

The control of Crenothrix in distribution mains by chlorination either by liquid chlorine or chloramine was described by W. F. Monfort[23] in 1919 and was based on destruction of the Crenothrix bacteria. Monfort discussed briefly with several references the relation of iron to the life processes of Crenothrix. Similar relationship probably exists as to manganese.

Ellis[24] also has written of "Iron bacteria in relation to incrustation of pipes."

The importance of small amounts of manganese in stimulating plant growth has been recently emphasized by McHargue.[25] He states that manganese functions in the synthesis of chlorophyl and carbon assimilation, that manganese stimulates plant growth up to 10 parts per million and above that amount is toxic. Several references are included in this connection.

That the change of state of oxidation of manganese, however, is always entirely biological does not seem plausible, despite the careful chemical experiments and regulation of pH by Kühr, since manganese is a well known carrier of oxygen, or a catalyzer. Living organisms merely utilize this characteristic property. In elementary chemistry it is a common experiment to mix manganese dioxide and potassium chlorate and to heat gently in a retort to produce a quiet stream of oxygen. Without the manganese dioxide there would likely be an

[23] This Journal, vol. 6, June, 1919, pp. 196-201; Proc. Ind. San. W. S. Assoc., convention April 9, 1919.

[24] Engineering, vol. 112, 1921, pp. 457–8; Chem. Abs., vol. 16, 1922, p. 601.

[25] Jour. Ind. Eng. Chem., vol. 18, February, 1926, p. 172.

explosion as the chlorate disintegrated, but in the presence of manganese dioxide the chlorate reduces quietly to chloride. The manganese probably passes through many changes of state of oxidation, although in the final product the manganese remains as dioxide. In the paragraph before his summary Kühr admits that "The manner in which the manganic dioxide retains manganous compounds and by what law it is governed still remain unexplained." It seems likely that manganese dioxide, MnO_2, combines by chemical action with manganous oxide, MnO, to form manganese trioxide, Mn_3O_4, which then is oxidized to the dioxide by either chemical or biological action.

Chlorine will readily oxidize manganous salts in natural waters to manganese dioxide and in these instances the pH is well under 10. Well waters containing manganese when chlorinated with gaseous chlorine will coat the glass syphon measuring tubes of Wallace and Tiernan machines so black that one cannot see through them.

On the other hand, somewhat in agreement with Kühr's work, Weston[26] ascribed greater difficulty of oxidation in removal plants to manganese than to iron. At the water works convention in 1921, he stated "Much less carbonic acid is required to prevent precipitation of manganese than of iron, and in one case it was possible to completely remove the iron and leave the manganese in practically permanent solution simply by stopping the aeration at the proper point."

That bacteria aid many obscure reactions, is, however, known in many instances and surmised in others and the above work is a decided addition to our specific knowledge. Similar conditions probably exist in iron removal plants and variation in bacterial content may explain the ease or difficulty that is experienced in accomplishing the complete removal of iron. Hale[27] in describing iron removal called attention to the fact that efficiency increased as the sand became coated with iron oxide and "ripened." This statement was questioned at that time by Milliken of the then well known New York Jewell Continental Filtration Company.

Manganese is more prevalent in water supply probably than has generally been suspected. It is contained frequently in clay and in water usually whenever iron is present to any extent, and probably comes from decaying leaves or vegetation. The difficulties caused

[26] This Journal, vol. 9, May, 1922, p. 492.
[27] This Journal, vol. 3, March, 1916, pp. 123–141.

by it in this country have been described several times recently. Baylis in 1924 also discussed the biological side of the question. The following are a few additional American references:

Kneeland, H. C.: Manganese in laundry and pipe lines. This Journal, Vol. 13, April, 1925, p. 436.

Corson, H. P.: Manganese in water supply. Uni. Ill. Bull. W. S. Series 13, 1916, pp. 144–204.

Appelbaum, S. B.: Manganese in ground water and its removal. Jour. Ind. Eng. Chem., Vol. 8, February, 1916, p. 160.

Hale, F. E.: Experience with manganese in the Croton water of New York City. Read at convention at Buffalo, New York, June, 1926. This Journal, (in press).

A PROGRAM FOR PROTECTING CHICAGO'S LAND TUNNEL SYSTEM[1]

By H. H. Gerstein[2] and Arthur E. Gorman[3]

During the last two years extensive investigations have been made in Chicago of the water tunnel system to locate possible sources of pollution, especially by leakage from sewers into adjacent shafts. This work was prompted by a marked difference in the bacterial quality of water samples collected from intakes at the lake cribs and those from intermediate points in tunnels between the lake intakes and the pumping stations served. As the result of studies made since 1924 a program for protecting water tunnel shafts has been adopted, the development of which will be presented in this paper.

In order to distribute water from its six intakes in Lake Michigan to the ten pumping stations, the City of Chicago has in operation about 58 miles of tunnels, 22 miles of which are under the lake and 36 miles under the city. A detailed description of these tunnels and the connecting land shafts was given by one of the authors in a paper in The Journal, Vol. 14, page 175, entitled "Experiences with Large Land Tunnels in Chicago" and, therefore, will not be repeated here

Unlike tunnels serving most of the large cities of this country those in Chicago are not under pressure. This fact, together with the loss of head resulting from flow through the tunnel, presents unusual complications which make the protection of the tunnel system against pollution from surface sources, and in particular from adjacent sewers, a serious problem.

In any level district the depth to which sewers and underdrains are laid usually determines the ground water level due to infiltration. In Chicago the ground water level in the vicinity of a tunnel shaft may dip to approximately the elevation of the water in the shaft, which is usually many feet lower than the adjacent sewers. Figure 1

[1] Presented before the Iowa Section meeting, November 3, 1926.

[2] Assistant Sanitary Engineer, Division of Water Safety Control, Bureau of Engineering, Chicago, Ill.

[3] Chief Sanitary Engineer, Division of Water Safety Control, Bureau of Engineering, Chicago, Ill.

illustrates the simple hydraulics involved in Chicago's tunnel pollution problem. Obviously the situation is dangerous when a sewer is located within a few feet or yards of a tunnel shaft. In any sewerage system there is liable to be more or less leakage from the joints in the sewers or the connecting house drains, especially when

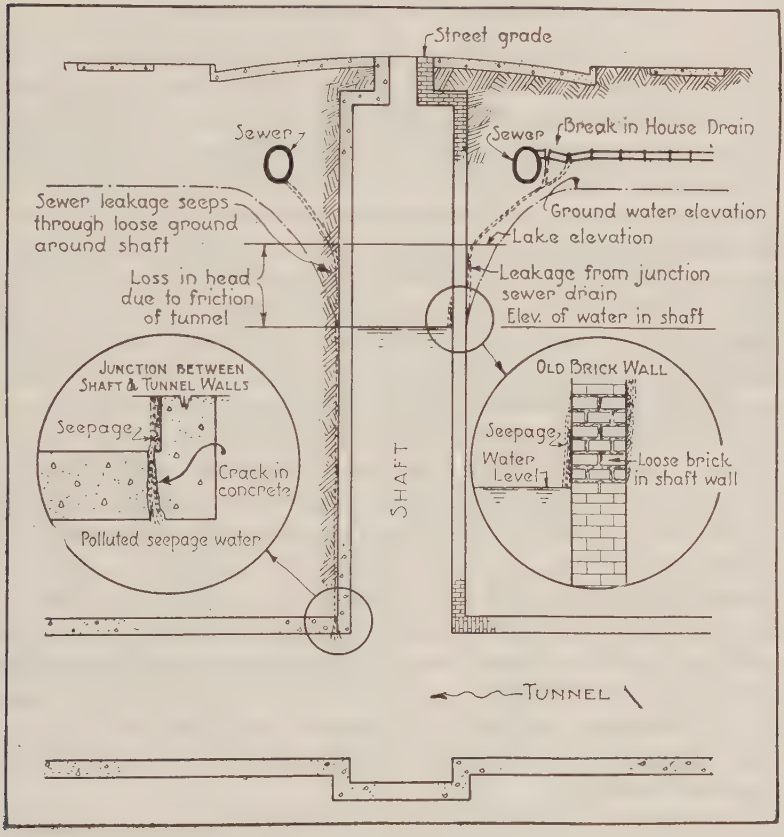

FIG. 1. SCHEMATIC DIAGRAM SHOWING MEANS OF ENTRANCE OF SEWAGE POLLUTED GROUND WATER INTO TUNNELS AND SHAFTS

the sewers are overtaxed as in Chicago. Under these conditions the leaking sewage will follow the flow of ground water and may enter the shaft. This combination of sewers adjacent to water tunnel shafts and a sewerage system generally undersize and subject to serious flooding, even after rains of only moderate intensity, consti-

tutes a serious potential hazard to Chicago's water supply. Considering the possibilities for leakage it is indeed fortunate that more leakage has not been experienced. This is considered due to the impervious clay which surrounds many of the larger sewers in Chicago and to the filtering effect of sandy sub-strata.

PENETRATION OF POLLUTED WATER

One of the most interesting studies carried out in connection with the tunnel investigations in 1925 was in relation to the rate of penetration of polluted water through the water column in a shaft down to the flowing stream of water in the tunnel proper. It is evident that, for control purposes, it is important that the time necessary for pollution entering a shaft to reach the water in the tunnel be known—particularly the minimum period. Prior to these studies it had been generally thought that there was little movement of the water in shafts and that moderate leakage at the surface was of no great consequence. However, the increased pollution of water in tunnels shortly after periods of heavy rainfall indicated that shaft leakage was apparently affecting the quality of the water in them. It was decided therefore to make a study of this problem.

A salt solution sprayed on the inner walls of the shaft above the water line was used as representing seepage into the shaft. The rate of penetration or diffusion downward in the shaft was determined by a sensitive electrical apparatus. Electrodes connected in series with a sensitive milli-voltmeter and a number of dry cells were lowered into the shaft to a pre-determined depth. When the salt solution traveling down the column of water in the shaft reached the electrodes a rise in the milli-voltmeter reading occurred. The interval between the time the salt solution was sprayed on the walls and the rise in deflection of the milli-voltmeter was recorded. Figure 2 shows the apparatus as set up.

Somewhat to our surprise it was found that there may be considerable movement of the water in a shaft overlying a tunnel, depending upon the depth of the shaft and the velocity of flow of the main stream of water in the tunnel. Traverses of several different types of shafts were made, comparisons of which are shown in figure 3. The time required for the salt solution to reach the tunnel varied from 6 minutes for a 25-foot shaft, in which there was violent disturbance of the water, to 345 minutes for a 50-foot diffusion in a deep shaft with little disturbance of the overlying water. Between

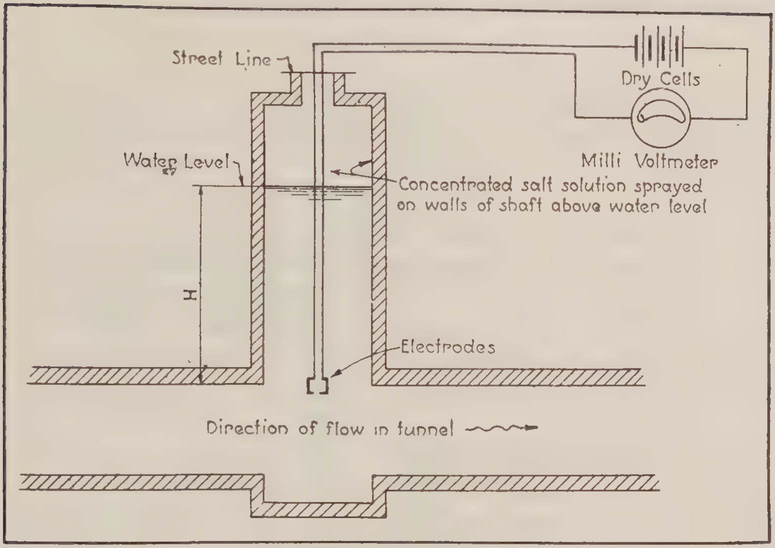

FIG. 2. APPARATUS USED TO DETERMINE THE TIME IT TAKES FOR SALT SOLUTIONS TO TRAVEL FROM WATER SURFACE IN SHAFT TO TUNNEL

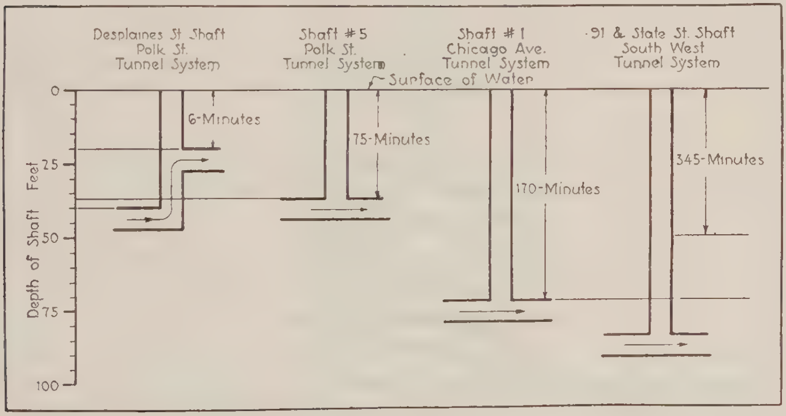

FIG. 3. TIME DETERMINED BY TESTS FOR SALT SOLUTION TO TRAVEL DOWN COLUMN OF WATER FROM SURFACE OF WATER IN SHAFT TO EYE OF TUNNEL IN VARIOUS TYPES OF SHAFTS

these extremes other periods were determined, but no general rule for prediction appears practical. A traverse of the Seneca Street shaft is shown in figure 4.

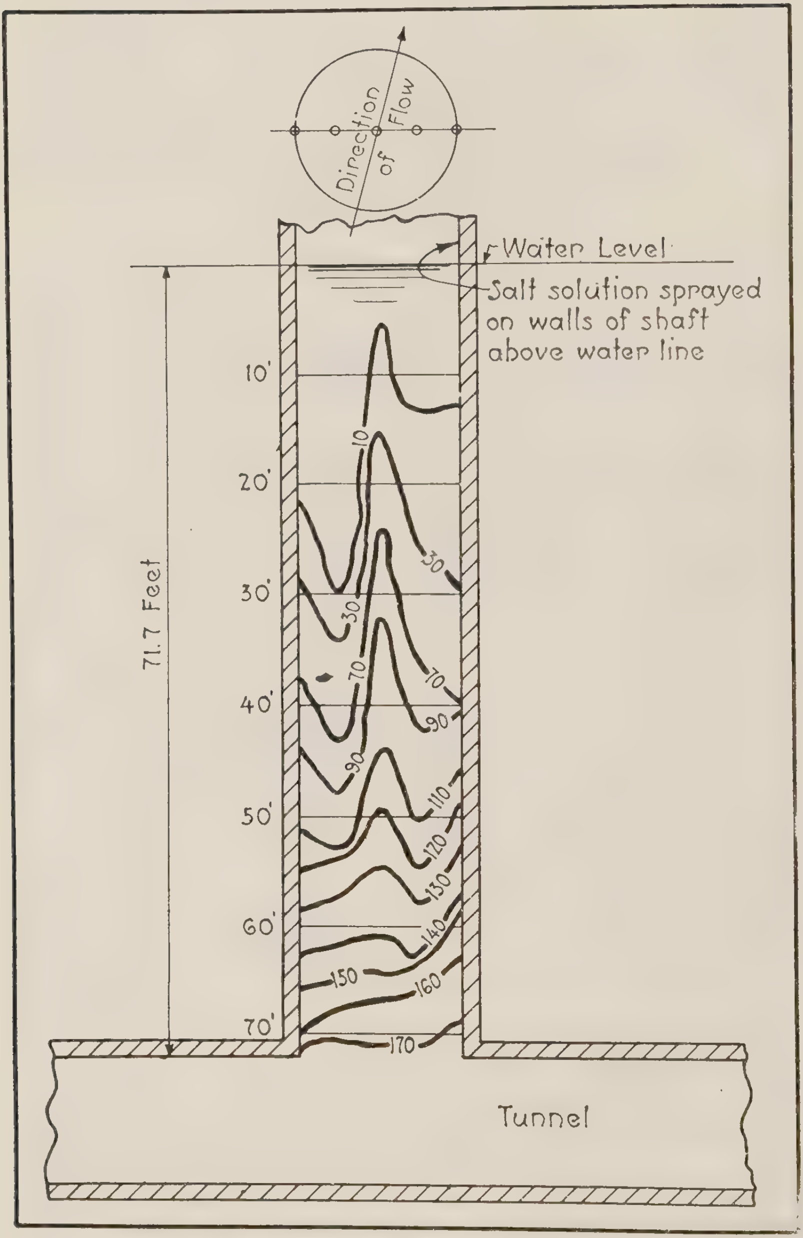

Fig. 4. Contours Showing Rate of Penetration of Salt Solution in Shaft No. 1, Chicago Avenue Tunnel System, August 24, 1923
Time in minutes

SEWAGE POLLUTION

The age of a sewer is no indication of its condition. During our investigations brick sewers laid some fifty years ago in blue clay were found in excellent condition with practically no outward leakage, while certain newer installations were found to be leaking badly. The most serious points of leakage noted in tile sewers were at the first joint in the house drain and in the lower portion of the joint in the main sewer. It is believed that in general the breaks in the house drain joints are due more to faulty back-filling than to careless tile laying. Some house drain connections were found seriously defective and indicated lack of competent supervision at the time of installation. If the drainage contractor, after having dug a trench for connecting a house drain to a sewer, fails to find the service junction indicated by the records he may even puncture a hole through the sewer and make an illegal and hasty connection, back-filling quickly so that his methods will not be detected. In several instances during the investigations of Chicago tunnel shafts, house drains were located passing directly over a back-filled shaft. Instances of house drains and sewers passing within a few feet of shaft walls are common. Figures 5 and 6 show typical cases. Conditions of this kind are, of course, positively dangerous and particularly so because leakage cannot be detected until indicated by actual pollution of the water supply.

From the standpoint of supervision over the safety of the public water supply in Chicago, these potential sources of pollution through tunnel shafts are really more dangerous than natural sources of contamination to the water surrounding the cribs. In the latter case, by studying such meteorologic factors as rainfall, direction of wind and barometric pressure, it is possible to predict within reasonable limits the degree of pollution of water at the intake cribs and the time of its arrival. On the other hand advance knowledge of pollution of the tunnel system through leakage into shafts is decidedly uncertain. Obviously, during and following periods of heavy rainfall, conditions are more or less dangerous and it is a general policy in Chicago to carry a higher dosage of chlorine in the water at these periods because of the uncertainty of tunnel pollution.

The route by which sewage polluted ground water may enter a tunnel shaft depends upon the type of construction of the shaft. Figure 1 illustrates the more common routes observed in the Chicago

investigations where both brick and concrete shafts and tunnels are used. The older brick shafts will readily permit the leakage of ground water. An excellent example is the leakage through the walls of shaft No. 10 of the 68th Street tunnel system. This brick

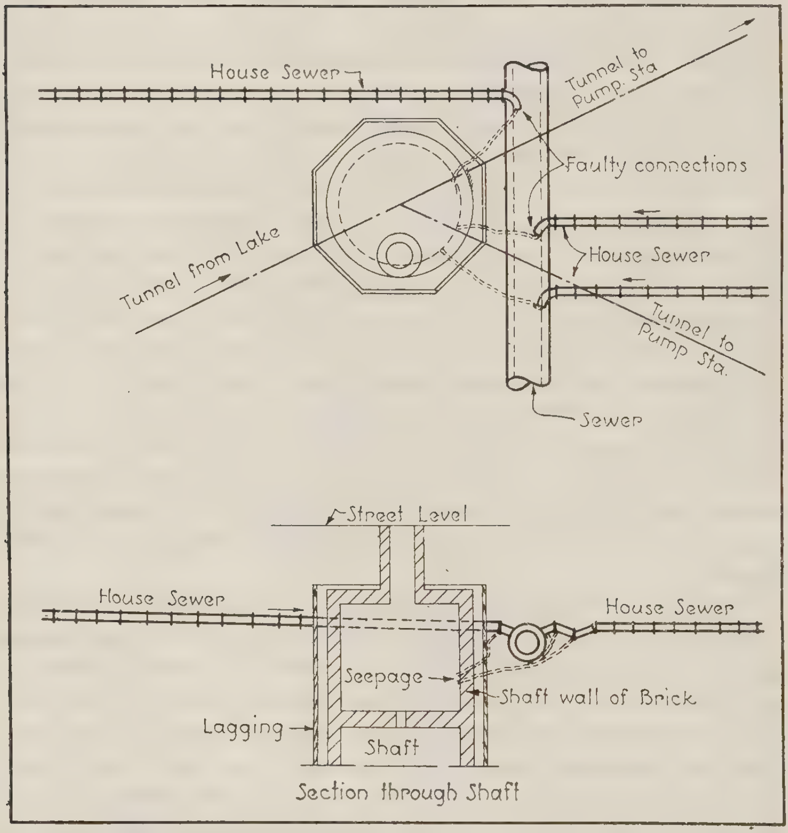

FIG. 5. POLLUTION OF GREEN STREET SHAFT BY LEAKING SEWER AND HOUSE DRAINS, 1924

shaft leaked ground water profusely. The entire inner wall, particularly below the water line, was found covered with a rust-colored gelatinous deposit varying in thickness from ½ to 3 inches. Under the microscope this material was found to contain innumerable filamentous organisms similar to crenothrix.

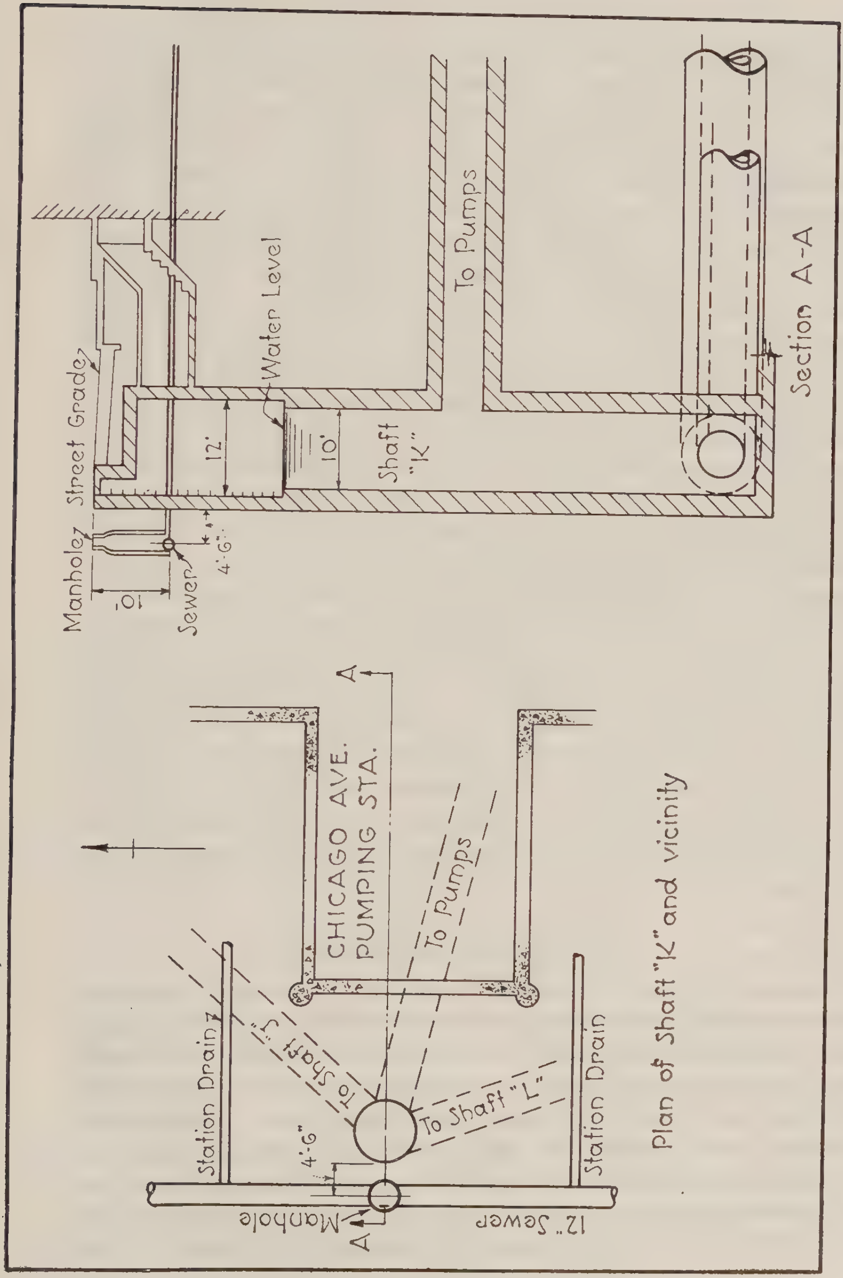

FIG. 6. DIAGRAM OF SHAFT "K" CHICAGO AVENUE PUMPING STATION SHOWING ADJACENT SEWERS

Note: When ends of sewer were blocked and the sewer flooded to a head of 10-feet evidences of leakage were seen inside shaft "K" above the water level.

LEAKAGE INTO CONCRETE SHAFTS AND TUNNELS

In the case of well constructed concrete shafts, our investigation indicated that the degree of leakage through the walls is relatively small. It has been found, however, that the depth to which surface water will penetrate between the outer wall of the shaft and the back-filling is beyond that generally considered possible. This penetration is apparently quite rapid and is believed to be facilitated by capillary action. Leakage of this water into the tunnel through cracks near the junction of the shaft wall and the arch of the tunnel lining may be expected. Inspections of shafts in two different concrete tunnels which were dewatered showed this clearly. In one of the best constructed concrete tunnels in Chicago's system an inspection showed considerable leakage through a crack at the crown of the tunnel about one foot back from the inner wall of the shaft. The leakage water had a strong tarry odor and, as the outer wall of the shaft had been coated with tar to make it impervious, it is probable that this leakage was ground water which had flowed downward along the shaft wall and thence through cracks into the tunnel. An inspection of the South Park concrete lined tunnel when dewatered showed marked leakage through the upper walls of the tunnel at points directly under the back-filled construction shaft, with relatively little leakage at other points. In this system three of the five shafts opening into the tunnel had been plugged by a 4-foot concrete core and the rest of the shaft back-filled with excavated material, the sheeting being left in. The numerous stalactites hanging from the roof and upper side walls of the tunnel at points below the location of the former working shaft indicated that ground water leakage had passed down along the sheeting and around the concrete core.

EFFECT OF PILE DRIVING

Underground conduits or structures in any city may be subjected to most unusual conditions not considered at the time of their design. The driving of piles directly over tunnels is a serious problem brought about by modern methods of construction, which was given little consideration when the first water tunnels were built. It so happens in Chicago that some of the older tunnels pass directly under land which is exceedingly valuable for high class apartment purposes. It is difficult to know the exact location of the tunnels, as some of the older field notes are not completely accurate. The result is that,

after laying out a system of piling so as to protect a tunnel, it is not known whether the piles as driven clear the tunnel or not. A policy which was recently adopted for the protection of tunnels against deep piling was to require at least ten feet clearance over the top of the tunnel. The contractors have complained that this reduces the bearing value of the piles and necessitates the placing of more of them. This is true, but it is considered necessary to hold to this policy for the protection of the tunnel system.

The vibrations following the impact of pile driving may have a serious effect in loosening the cement joints of terra cotta tile sewers. The impact of the driver on the pile may so affect well settled sub-strata and backfilling as to permit an unusual penetration of ground water. This fact was clearly indicated in connection with leakage in the fall of 1925 into a land shaft at Seneca Street in a branch tunnel to the Chicago avenue pumping station. This shaft was located in the parkway and had not been disturbed since constructed, the adjacent property being vacant. A sampling pump is set up in this shaft. Daily analysis of the water passing through the tunnel at this point had been made for almost a year and showed no unusual degree of pollution. However, as soon as the foundation contractors began to work on the vacant property the bacterial quality of the water deteriorated seriously. By means of steam shovels approximately 14 feet of material was excavated prior to driving the foundation piles. In excavating, the east side of the shaft wall was completely exposed. Water which collected in the excavation is believed to have been responsible for the early pollution of the water in the tunnel, probably due to lateral penetration through the shaft walls. The pile driving contractor was notified that no piles should be driven closer than ten feet to the shaft wall. As soon as the driving commenced there was a marked increase in the pollution of the water in the tunnel. In pile driving in Chicago where the sub-strata are sand and clay a jet method is used. In this process a jet of water is forced into the ground at the point the pile is to be driven, which effectively loosens the soil to a depth of approximately 30 feet. The pile is then inserted and driven. The preliminary jet introduces surface water to a considerable depth into the sub-strata. The subsequent driving of the piles effectively disturbs the deeper sub-strata and permits considerable penetration of ground water. It was not until pile driving in the vicinity of this shaft was completed that the quality of the water returned to normal. Figure 7 shows the effect of pile driving over tunnels and near shafts.

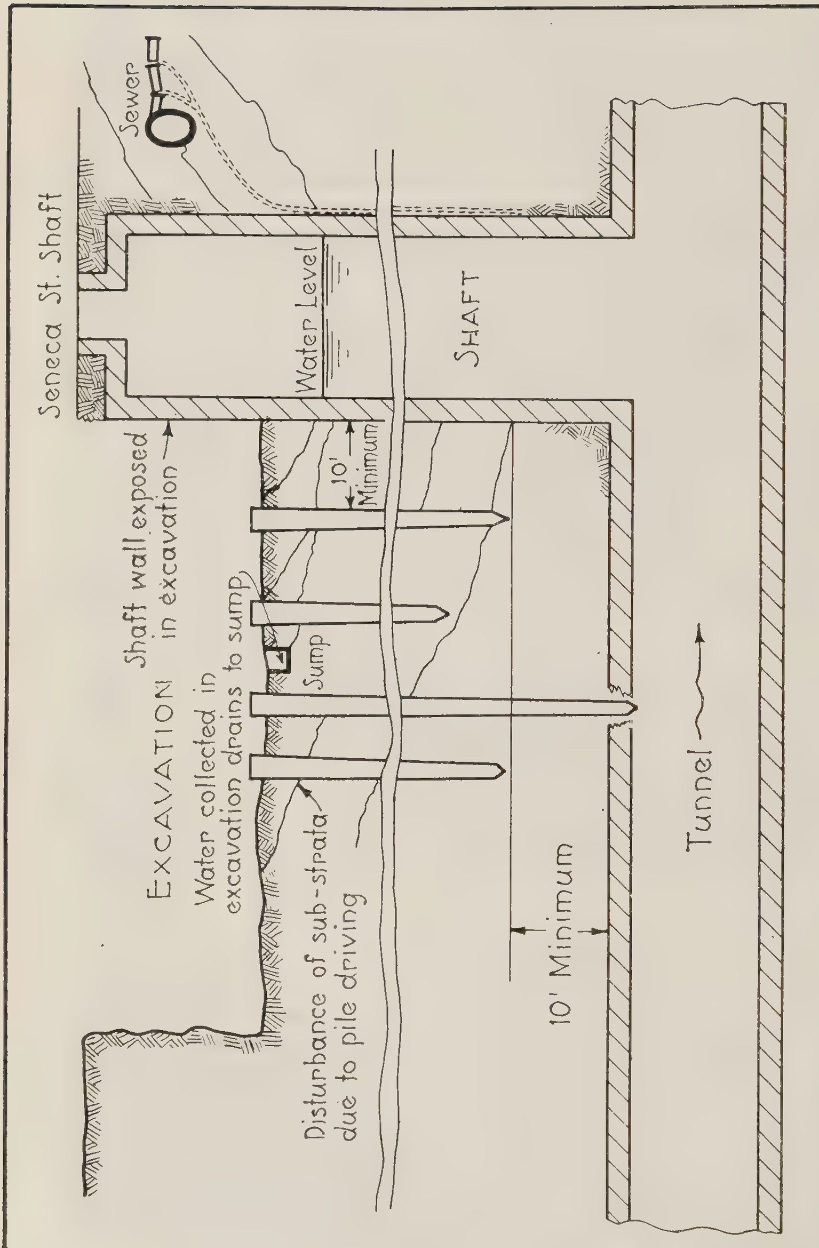

FIG. 7. DIAGRAM SHOWING PILING OVER TUNNEL AND NEAR SHAFT, ILLUSTRATING PENETRATION OF GROUND WATER THROUGH SUBSTRATA DISTURBED BY PILE DRIVING

PROTECTING TUNNEL SHAFTS

The Department of Public Works has adopted a general policy, with the recommendation of City Engineer John Ericson, which it is believed will be effective in protecting the tunnel shafts from leakage from sewers and house drains. This policy is to replace all sewers and house drains which are within 50 feet of tunnel shafts by cast iron water pipe with leaded joints. By carrying out this program the pollution by sewer leakage was effectively eliminated at the Green Street shaft and the suction well at the Harrison Street pumping station. In 1924 and 1925 investigations were made of the location and condition of all sewers in the vicinity of tunnel shafts, with the object of relaying them with cast iron pipe as soon as possible. Projects of this kind have been recently completed at the Lake View and 68th Street pumping stations, and work is now in progress at the Chicago Avenue pumping station.

Since Chicago's water supply program contemplates the use of land tunnels to deliver filtered water from filtration plants to pumping stations many miles inland, either by gravity or slight pressure, it may be readily realized that for public health reasons the protective program outlined must be continued.

THE ELECTROLYSIS SURVEY COMMITTEE OF BALTIMORE CITY

By H. Carl Wolf[1]

Officials of the Baltimore City Water Department early in 1922 requested the Public Service Commission of Maryland to take steps to organize a committee for the purpose of studying electrolysis conditions in the city and of mapping out a plan for improvement. Although the Commission was without direct authority in such a matter, nevertheless it asked representatives of those concerned with underground structures to meet and consider the problem. The Electrolysis Survey Committee of Baltimore City was subsequently formed, a representative was named by each of the following agencies, and the writer was elected chairman: Municipal Water Bureau, Municipal Electrical Commission, Municipal Police and Fire Alarm System, Consolidated Gas Electric Light and Power Company (Gas and Electric), Chesapeake and Potomac Telephone Company, American Telephone and Telegraph Company, United Railways and Electric Company, Washington, Baltimore and Annapolis Electric Railroad Company, Pennsylvania Water and Power Company, Baltimore and Ohio Railroad Company, Western Union Telegraph Company, Postal Telegraph Company, and Maryland Pipe Line Company.

The United Railways and Electric Company operates a 600-volt direct current rail return system with tracks covering pretty generally the streets in the city, and extending out into the suburbs in all directions. The Baltimore and Ohio Railroad Company has an electrified tunnel extending for one mile through the business section, and operated at 600 volts direct current. The Washington, Baltimore and Annapolis Electric Railroad Company has a short stretch of line in one section of the city operated at 600 volts d.c., changing to 1200 d.c. outside of the city limits, where it parallels gas and water mains for several miles. The Electric Company operates a 110–220 volt 3-wire d.c. net work in the business section. The electric,

[1] Chief Engineer, Maryland Public Service Commission, Baltimore, Md.

telephone, railway, and telegraph companies have extended systems of underground and overhead cables covering every section of the city, while the Water Power Company has certain transmission feeder cables through a portion of the city. The conduits, with the exception of those used by the telephone companies, are built and maintained by the city through the agency of its Electrical Commission. This system is being rapidly extended and as conduits are built, all overhead wires on streets must be removed. The Water Bureau and the Gas Company have comprehensive pipe systems in every direction. The Maryland Pipe Line Company has a short stretch of line through which oil is piped into the city, which is a part of its transcontinental system.

PRELIMINARY STUDIES

The first question that presented itself to the committee was whether or not a general survey of electrolysis conditions in the city should be made as a starting point for future work. It was suggested that the National Bureau of Standards be asked to assist in the work and the cost be borne by the underground structure owning agencies in proportion to the amount of equipment owned by each. From a cursory review it appeared that conditions were not as bad in Baltimore as had been found in some other cities, and hence it was decided to first make a compilation of all the information collected by the various agencies in the city who had been studying the problem during the past few years. Accordingly, maps were prepared showing potential readings taken during the previous years by each agency and indicating points where failures due to electrolysis had occurred. Other pertinent data were assembled. From these it appeared that there were only two sections of the city in which dangerous conditions existed, and it was in these sections where practically all failures attributable to electrolysis during the past few years had occurred. Continual changes in the underground pipe and cable systems were causing such rapid shifts in drainage paths and in rail potentials that it was deemed advisable to concentrate on these sections where dangerous conditions had been found, rather than to undertake a comprehensive survey of conditions through the entire city.

ORGANIZATION OF INVESTIGATING COMMITTEE

A sub-committee was formed, consisting of technical assistants from the water department, the electrical commission, the railways

TABLE 1

Potential readings between underground structures at Belair Road and Erdman Avenue, February 9, 1926

a. Averages of potential readings (ten-second intervals)

	WATER MAIN	GAS MAIN	EARTH	UNITED RAILWAYS RAILS	CHESAPEAKE AND POTOMAC CABLE SHEATHS	CONSOLIDATED AND UNITED RAILWAYS CABLE SHEATHS	DRAIN WIRE SHERWOOD SOUTH OF DARLEY
Water Main	0	0.35+	0.67+	0.78+	4.77+	5.43+	13.24+
Gas	0.35−	0	0.32+	0.43+	4.42+	5.08+	12.89+
Earth	0.67−	0.32−	0	0.11+	4.10+	4.76+	12.57+
United Railway rails	0.78−	0.43−	0.11−	0	3.99+	4.65+	12.46+
Chesapeake and Potomac cable sheath	4.77−	4.42−	4.10−	3.99−	0	0.66+	8.47+
Consolidated and United Railway sheath	5.43−	5.08−	4.76−	4.65−	0.66−	0	7.81+
Drain wire*	13.24−	12.89−	12.57−	12.46−	8.47−	7.81−	0

* Sherwood Avenue south of Darley Avenue—voltage drop from here to negative bus estimated 1 volt. Readings were taken for fifteen minutes at ten-second intervals beginning 10:20 a.m.

b. Details of readings at ten-second intervals between rail and water mains

TIME	10:20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
0	+0.5	+0.1	+0.2	+0.3	−1.3	−0.8	−0.7	−1.8	−1.6	+1.3	−1.6	+1.1	−0.9	−1.0	−1.9
10	−1.3	−0.8	−0.1	−1.6	0.5	−0.5	−0.7	−1.0	−1.0	+0.4	−0.3	−2.6	−0.8	−1.6	−0.5
20	−0.3	+2.2	−0.2	−1.2	−1.3	−0.6	−0.4	−0.1	−1.5	−1.6	−2.2	+0.2	+0.4	−1.7	−1.1
30	0.0	−0.5	−0.3	−1.1	+1.3	−0.2	−0.7	−1.5	−3.2	−0.8	−3.3	−3.0	+0.5	+0.5	−2.2
40	−3.2	−0.5	−1.4	−1.2	+0.2	−1.6	+0.1	−2.1	−0.4	−1.3	−0.1	−1.5	−0.6	−1.0	−1.2
50	−0.8	−0.6	+1.2	−1.6	−1.6	−1.7	−1.1	−1.4	−0.6	+1.6	−0.2	−0.6	−2.3	−1.1	−0.6

Average = 0.781−.

TABLE 2

Typical instantaneous potential readings between telephone cables and other underground structures

DATE	LOCATION	MANHOLE BOTTOM	RAILROAD RAILS	WATER MAIN	GAS MAIN	TELEPHONE CABLES TO CITY CABLES	CITY CABLES TO SUMP	TIME
September 29, 1926	Philadelphia Road and Streeper	0.6−		0.6−		0.2+	0.6−	10:25 a.m.
	Philadelphia Road and Belnord	0.6−		0.8−		0.1+	0.4−	10:35 a.m.
	Philadelphia Road and Glover	0.6−			0.4−	0.1−	S−	10:45 a.m.
	Fayette and Rose	0.8−	1.6−		0.8−	0.2−	0.2−	10:55 a.m.
	Fayette and Port	0.6−	1.2−	0.4−		0.2−	T−	11:25 a.m.
	Fayette and Bradford	0.8−	1.2−		0.4−	0.2−	0.6−	11:30 a.m.
	Fayette and Madeira	0.4−	1.6−	0.8−		0.2−	0.6−	11:40 a.m.
	Fayette and Duncan	0.6−	1.4−		0.6−	0.1−	0.4−	11:50 a.m.
	Fayette and Castle	0.8−	1.4−		0.6−	0.2−	0.4−	12.00 noon
	Fayette and Chapel	0.8−	1.6−		0.6−	0.2−	0.6−	1:10 p.m.
	Fayette and Wolfe	1.0−	1.2−	0.6−		0.2−	0.4−	1:20 p.m.
	Fayette and Bethel	0.6−	1.2−			S−	0.2−	1:45 p.m.
	Fayette and Aisquith	0.4−	1.0−	0.4−		0.2−	0.4−	2:30 p.m.
	Fayette and East	0.4−		0.4−		0.1+	0.4−	2:40 p.m.
	Fayette and High	0.2−		0.2−		0.2−	S−	3:05 p.m.
	Fayette and Harrison	0.2−				0.2−	0.4−	3:45 p.m.
	Fayette and Frederick	0.2−		S+		S+	0.4−	4:00 p.m.
September 30, 1926	Fayette and E. Gay	S−	1.8−	0.2−		0.2+	0.4−	9:20 a.m.
	Fayette and Holliday	0.2−	1.0−			S−	S−	9:30 a.m.
	Fayette and Guilford	0.2−	1.2−			S−	S−	9:40 a.m.
	Light and Baltimore	0.2−	1.0−	0.1+		0.4−	0.4−	11:10 a.m.
	Redwood and Hopkins	0.6−	1.6−			0.2−	0.4−	1:20 p.m.
	Redwood and Liberty W.	0.6−	1.6−	0.2−		0.2−	0.4−	1:50. p.m
	Redwood and Eutaw	0.8−	1.2−	0.8−		0.2−	0.4−	2:15 p.m.
	Redwood and Greene	0.8−		1.2−		1.6−	S+	2:35 p.m.
	Redwood and Pennsylvania Avenue	0.8−				1.6−	0.2+	2:55 p.m.

company, and the gas company, under the leadership of Mr. F. T. Iddings of the telephone company, whose name in this section is synonymous with electrolysis, and a detailed survey was begun of one section in the eastern part of the city in which the worst conditions had been found. The recent joining together of two previously isolated water systems, the rapid development of all underground systems due to industrial expansion, and an absence of comprehensive mitigative measures all pointed to the advisability of the survey in this section. Later, other sections were studied in a like manner, and mitigative measures agreed upon by members of the committee. Measurements were made of the potential gradient on the rails and the instantaneous potential differences between all structures at strategic points, and these were plotted against the railway loads. In some cases where great potential differences were found, the amount of current being returned by the underground systems was measured. The telephone company, on its own initiative, has for some years been making a general survey of electrolysis conditions over its cable system which covers practically the whole city. This survey during the last year was extended to all underground structures in the vicinity of the company's cables. In this way a fair picture of conditions generally was found.

Results of the studies and surveys of the sub-committee are laid before the general committee and made available to all parties concerned. . Any recommendations made by the sub-committee are considered and passed upon by the general committee and a method of procedure decided upon. All problems are approached with a spirit of coöperation, and for this reason, no vexatious questions tending to halt improvement in conditions nor any problems which were incapable of solution have yet arisen before the committee. Mitigative measures have generally fallen into three classes,—coöperative construction, proper drainage, and construction of automatic substations by the railways company.

DRAINAGE AND AUTOMATIC SUBSTATIONS

Before any construction of any importance is undertaken by any company or city department, plans are first discussed in committee meetings; where it appears likely that electrolysis conditions will be unbalanced, changes are suggested and where changes appear impractical, mitigative measures are provided for. Studies in the area affected are taken both before and after the construction is

completed. The railways company has evidenced great willingness to supply adequate drainage wires and the other coöperating agencies have freely availed themselves of this privilege. In some cases, overdrainage has been found to result, due to shifting conditions. Each of the agencies involved provides a certain amount of drainage for its own system. All of these drainage wires are being made a part of the general drainage system. The railways company makes a continual investigation of its bonds; for the past few years less than 2 per cent of all bonds in the city have been found to be defective, which fact is a potent factor in reducing electrolytic losses. This company has also adopted a program for the installation of additional sub-stations—all automatic—their locations being worked out as far as possible to improve electrolysis conditions.

DIFFICULTIES WITH JOINTS

Pipe joints and insulated rail joints have resulted in some little annoyance due largely to the uncertain conditions which they produced before the committee started to function. The removal of insulating joints on either side of a submarine cable and a provision for additional drainage eliminated one case of electrolysis which had been troublesome for years. In another case, an insulating joint was found to have been installed in the rails near a sub-station, causing a potential gradient of 30.5 volts per 1000 feet. Removal of the joint reduced the gradient to 4.3 volts. Cement joints used in gas pipes have been found to result in some flow of current between gas and water pipes; in one case twelve amperes were found passing through a bond in the basement of a residence. It is believed that leadite joints in water pipes cause a very uncertain condition, due largely to the rapid decrease of resistance with age. It is evident that some method for the protection of water and gas services which closely approach other structures should be developed. With the rapid spreading out of both of these systems and the meeting of the services with small telephone block cables at very vulnerable points, it is not always expedient to supply proper electrical protection to these small ends. The water department is resorting to the use of cast iron for services of 2 inches and over, in order to reduce the conductance and the liability to damage. It is true, of course, that damage to services and block cables is not as serious as that to feeder and transmission systems, but it can nevertheless be very troublesome.

ADVANTAGE OF COÖPERATIVE CONTROL

The most important thing that the Electrolysis Survey Committee has brought about is a manifestation of a spirit of coöperation which motivates all of the underground structure owning agencies in the city. A medium is provided by which differences of opinion can be ironed out and steps taken that will react to the benefit of all. Isolated remedies applied by a single agency are no longer thought of. The total number of failures due to electrolysis has shown a slight decrease since the committee started its work, which fact, in view of the rapid expansion of the underground systems during the past few years, indicates progress in mitigative measures. Inasmuch as many failures occur as a result of conditions which have been existing for a number of years, it is evident that the full benefit of the committee's work will not be apparent for a long time. Certainly it is true that Baltimore is remarkaby free of electrolysis troubles, but it is the aim of the committee to effect even greater improvement, inasmuch as the damage done by electrolysis is in no way measured by the number of failures which occur.

The coöperative method which has been the rule in Baltimore for the past five years commends itself for the attacking of the vexatious electrolysis problem and is worthy of emulation in other cities.

EXPERIENCES WITH GOOSE-NECKS, OR SERVICE CONNECTIONS, OF LEAD, WROUGHT IRON AND COPPER[1]

By Emil L. Nuebling[2]

The service pipes and connections of the Reading, Pa., water works were and are still installed by and at the expense of the property owners. The work is generally performed by a plumber. No rule or regulation, however, prohibits any other competent person from installing service lines.

The corporation cocks were always installed by the operators of the water works. The original cocks had a tapered tail piece which was driven into a drilled and taper-reamed hole located at the top of the water main. A pliable connection with the service pipe was made with a lead goose-neck. This method was also used after the introduction of the first modern tapping machine, which permitted the making of $\frac{1}{2}$- to 1-inch diameter taps. When it was observed that some service installations were being made with light weight pipe, the water works officials had rules adopted specifying the minimum permissible weights of lead pipe that should be used. The specified weights were then listed as Class A. A. No serious trouble was thereafter experienced with service pipe connections until after the introduction of a larger tapping machine, which permitted the making of taps up to 2 inches in diameter.

Since no additional rule was made as to the weight requirements, of the larger sizes of lead pipes and connections, the same class as specified for the smaller sizes was used in installing the larger sizes. Some time after the installation of a number of the larger sizes of service connections, a good percentage of them split open; especially those of the largest size. The writer, who was then in charge of the water works, was surprised at the results of calculations made of the strengths of the various sizes of lead pipes. The so-called classes, "Strong," "Extra Strong" and "Extra Extra Strong," did not carry the same degree of strength throughout the different sizes of pipes,

[1] Presented before the Chicago Convention, June 9, 1927.

[2] Consulting Engineer, Reading, Pa.

but, under any class, the strength of the smaller diameters of pipes was far in excess of requirements and that of the larger sizes was considerably below the pressures to which they were subjected. This is clearly shown in table 1, which shows, for example, that a ½-inch "Extra Strong" lead pipe will safely withstand a working pressure of 220 pounds per square inch, while a 2-inch "Extra Strong" lead pipe will only take care of 69 pounds per square inch.

The regulations pertaining to service pipes were then changed to permit lead pipes of the following minimum weights: ½-inch, 2 pounds; 4-inch, 3½ pounds; 1-inch, 6 pounds; and to prohibit the use of lead in service pipes or connections in sizes of 1¼ inches in diameter and larger. For these sizes a flexible joint (permitting some settlement of main line, service line or both without pulling out or breaking off at the joints), was then required. The rule as adopted is,

> Where 1¼-, 1½-, and 2-inch corporation cocks are used, the service pipe shall be connected without the use of lead pipe by means of straight long turn elbows, nipples and "Kewanee" or all brass unions. All fittings other than unions shall be either galvanized wrought or malleable iron, lead-lined wrought or malleable iron or cast iron. The first elbow shall be attached to the corporation cock and followed with nipples, union and second elbow for a distance of approximately nine diameters of the pipe from center to center of elbows. The direction of this portion of the connection shall be approximately in line with the water main. The next portion of the connection shall consist of a nipple and a third elbow and be not less than six diameters in length, between elbow centers, and shall extend upwards or downwards to reach the proper depth of the service pipe. The outlet of the third elbow shall run at right angles with the main.

The corporation cock for these installations was inserted horizontally on the side of the main pipe line. It was and is now rather difficult to purchase long turn elbows, because so few supply-houses keep them in stock. So, after a trench had been left open for several days, while the plumber was endeavoring to get hold of some long turn elbows, the nuisance of the open trench was abated by permitting the plumber to substitute short turn elbows, which, with three of them in the line rather closely bunched, did not aid the flow of water greatly by reason of the excess friction created.

COPPER SERVICES

The copper service pipes and connections, recently put upon the market by one of the largest manufacturers of water works brass

TABLE 1

Relative strengths of lead and copper service pipes

The pipes will withstand, in addition to the safe internal pressures listed, a 50 per cent increase allowed to take care of water ram. The ultimate cohesion of lead is taken at 2000 and that of copper at 30,000 pounds per square inch, each with a factor of safety of 5.

LEAD PIPE										MUELLER COPPER PIPE			
Extra Strong—A. A.					Extra Extra Strong—A. A. A.								
Nominal inside diameter	Actual outside diameter	Calculated inside diameter based on outside diameter and weight	Weight	Safe internal pressure	Actual outside diameter	Calculated inside diameter based on outside diameter and weight	Weight	Safe internal pressure	Outside diameter	Thickness B. W. G.	Thickness	Safe internal pressure
inches	*inches*	*inches*	*pounds per foot*	*pounds per square inch*	*inches*	*inches*	*pounds per foot*	*pounds per square inch*	*inches*		*inches*	*pounds per square inch*
½	0.96	0.5255	2.5	220	1.04	0.5542	3.0	233	⅝	18	0.049	744
¾	1.21	0.7487	3.5	164	1.27	0.7617	4.0	178	⅞	16	0.065	698
1	1.48	0.9819	4.75	135	1.59	0.9895	6.0	162	1⅛	16	0.065	523
1¼	1.76	1.2444	6.0	110	1.83	1.2674	6.75	118	1⅜	16	0.065	418
1½	2.07	1.4898	8.0	104	2.15	1.5163	9.0	111	1⅝	15	0.072	389
2	2.51	1.9941	9.0	69	2.61	2.0011	10⅞	81	2⅜	14	0.083	301

TABLE 2

Desirable materials for services and goose-necks

DIAMETER	MATERIALS FOR SERVICE PIPES	MATERIALS FOR GOOSE-NECKS
inches ½ ¾ 1	Copper or brass, lead, lead or tin-lined genuine wrought iron, genuine galvanized wrought iron	Copper Lead
1¼ 1½ 2	Copper or brass, cast iron*, lead or tin-lined genuine wrought iron, genuine galvanized wrought iron	Copper
Above 2	Cast iron, genuine galvanized wrought iron	No goose-necks

* If made heavy enough to withstand external forces including rough handling.

goods, have demonstrated their great value as mediums for joining service lines to corporation cocks as well as good materials for the service pipes. The strengths of these pipes as shown in table 1 should be compared with corresponding sizes of lead pipes. The strength to resist internal pressure is considerably above the actual requirements, brought about, no doubt, by an added thickness of metal for withstanding external pressures.

Sizes up to and including one-inch in diameter have been on the market and in use for some time. When copper pipes and connections are available and used for the larger sizes then all future difficulties with these service pipes and goose-necks will, undoubtedly, be avoided.

DESIRABLE MATERIALS FOR SERVICES

In the opinion of the writer the desirable materials for service pipes and goose-necks of the various sizes are listed in table 2. The materials are listed in the order of preference. The list does not contain cement-lined pipe, because the writer has had no experience with it.

PROGRESS OF WATER TREATMENT ON RAILROADS[1]

By R. E. Coughlan[2]

To the men who are in daily contact with the trouble experienced from the use of water unsuitable for the generation of steam, no argument is necessary to show the need of water treatment.

As 90 per cent of a railroad's water supply is utilized for steam making purposes, this subject has been one of importance for many years. Scale forming salts must be removed and corrosion retarded, if economical results of boiler operation are to be obtained.

Corrosion of boilers has been one of the problems of railroads for many years. In 1868, the old American Railway Master Mechanics Association reported on this subject, laying particular stress upon the quality of the water as being one of the important factors.

Practically all railroads have some soft water, as well as water which should be treated before it is used in boilers.

Our present day water softening plants are the outcome of a process invented by Dr. Thomas Clark of Aberdeen, Scotland, in 1841. Previously, Cavendish in 1776, and Henry, in the latter part of the eighteenth century, discovered that caustic lime or lime water, when added to a natural water, would throw the carbonates of lime and magnesia out of solution. Clark was the first to apply this principle to soften water. It was some years later that Porter suggested the use of soda ash with lime. This was the start of the lime and soda ash process now used extensively. Although the principles and reactions of water softening have been known for many years, it has only been since 1880 that much advancement has been made in the United States.

The early water softening plants were of the intermittent type and many experiments were necessary before our present day continuous type of plant was perfected. Even today, the intermittent

[1] Presented before the Boiler Feed Water Studies' meeting, Buffalo Convention, June 9, 1926.

[2] Supervisor of Water Supply, Chicago and North Western Railway Company, Chicago, Ill.

type of plant is used on many installations where local conditions warrant it.

For a number of years, the reagents were added directly to the water in the locomotive tank. The resulting sludge being carried into the boiler caused considerable foam trouble which handicapped efficient treatment.

The progress of complete treatment of water before it entered the boiler has been marked by very interesting results and surprising revelations to the mechanical men who are responsible for the efficiency of boilers. In the early days, it was considered that anything that was wet could be utilized for steam purposes. If the boiler failed, due to leaking or foaming, it was taken as a matter of course. The larger locomotives, longer runs and faster schedules required increased efficiency of the locomotives. This demanded better water for steam making and water treatment has met the demand.

The western railroads, due to the poor quality of the water available in their territories, have taken the initiative in the installation of water treating facilities, and it is on the western railroads that the most marked improvement has been noticed.

WATER TREATMENT ON THE CHICAGO AND NORTH WESTERN RAILWAY

On the Chicago and North Western Railway, practically all of the water supplied to boilers, except that obtained from lakes and rivers of northern Wisconsin and northern Michigan, requires treatment. Partial treatment and internal treatment have been used for many years. The extensive water treatment program by the Chicago and North Western Railway was started in 1903 when sixteen lime and soda ash treating plants were built in Iowa, where the water is hard, due to the large quantity of sulphates of magnesia and lime contained in solution. These were the pioneer water softening plants in that section of the country, and have been added to from time to time, until, at present, there are forty-seven lime and soda ash water softeners in operation and ten more under construction. These are supplemented by partial treatment and internal treatment where local conditions warrant it. Intermittent types of softeners were the first installations.

In 1922, the first continuous type softener was installed. Where internal treatment is used, this treatment is controlled by means of chemical tests made on samples of water taken from the boilers at

each terminal. Simple feeding devices regulate the amount of treatment.

The 1925 volume of the Railway Engineering and Maintenance Encyclopedia states that approximately 1000 water softeners are now operated by the railroads of the United States, removing 100,000,000 pounds of scale annually at approximate saving of $13,000,000 per year.

This annual saving is directly reflected in the operating report of each railroad so equipped. The boiler failures report of the Chicago and North Western Railway Company for 1910 shows 2132 failures, chargeable to water conditions. The same report for 1925 shows 37 failures. The monthly boiler failure report for February, 1910, shows as follows:

Boiler failure report for month of February, 1910

Cause of failure:	
Leaking flues	319
Leaking fireboxes	22
Leaking arch tubes	0
Flues burst	3
Arch tubes burst	30
Foaming	17
Total	394

The same report for February, 1926, shows as follows:

Boiler failure report for month of February, 1926

Cause of failure:	
Leaking flues	0
Leaking fireboxes	0
Leaking arch tubes	0
Flues burst	0
Arch tubes burst	0
Foaming	0
Total	0

Water treatment is one of the essential factors which make it possible to obtain the longer daily mileage which most railroads are now receiving from locomotives in passenger service. A few years ago, it was the practice to change locomotives about every 100 to 150 miles. Now many railroads that are equipped with water softening plants use only one locomotive for continuous runs of much longer mileage.

The Chicago and North Western Railway now operates locomotives in passenger service from Clinton, Iowa, to Omaha, Nebraska, a distance of 350 miles. These locomotives make a round trip of 700 miles each day. Another western railroad operates locomotives in passenger service 600 miles without change, while still another has completed test runs of over 1700 miles, one locomotive pulling the train the entire distance.

PITTING OF FLUES AND BOILER CORROSION

With the problem of incrustation of boilers practically under control, more attention is now being given to the pitting of flues and the corrosion of boiler sheet. Many theories as to the cause of this trouble have confused the issue. Many committees have held symposiums on the subject. The railroad water service engineers have not been idle, although their work has been somewhat hampered, due to incomplete records and the increasing evaporating power of boilers. When it was found that removing the scale did not prevent corrosion, further studies have been made along three special lines, namely:

1. Use of feed water heaters to eliminate oxygen
2. Counter-electrical potential devices
3. Excess treatment

The first two of these methods are still in the experimental stage, each method having its respective merits and adherents. The excess treatment method has shown great possibilities where it is practicable to apply it in the railroad service. This method, proven in the laboratory, consists in the addition of an excess of caustic soda, caustic lime or sodium carbonate over that required to combine with the scale forming salts. The success of this treatment depends upon uniformity of treatment over an entire locomotive district to prevent foaming. Where it is possible to secure this uniformity, high concentration of alkaline salts are carried in the boilers with practically no foam trouble.

The Chicago and North Western Railway Company has a locomotive district where 50 per cent of the natural water contains over 50 grains per gallon of sodium carbonate. By treatment of the remaining water to a similar composition, a concentration of over 8 per cent normal alkalinity is carried without trouble. Pitting and corrosion on this district is unknown and, needless to say, the boilers

are clean. Additional lime and soda ash softeners are being installed on other locomotive districts as rapidly as funds become available, so that in a short time this method of treatment will be in general use.

One of the railroads having 71 lime and soda ash softeners in operation is treating the water to less than 1 grain per gallon hardness, leaving in the water an excess of lime and soda ash for the purpose of eliminating pitted flues. This program was started early in 1922, and very gratifying results had been obtained. The boilers carry a very high percentage of alkaline concentration, with very little trouble.

The quality of the material used in boiler construction has also been thoroughly investigated. At the present time, most of the railroads have standard specifications for boiler steel. These specifications are strictly adhered to in order to avoid the use of non-homogeneous steel which may set up electrolytic reaction, leading to corrosion.

Protective coatings of lead or similar material have also been used with varying degrees of success.

While the entire principles of water softening and the control of corrosion may be explained theoretically in very simple terms, practical applications are sometimes very difficult. Experimenting with the boiler of a locomotive in operation is entirely different from research work conducted in a laboratory. Foam trouble and priming cannot be tolerated. The water service engineer must be sure of the results. Movement of trains safely is the first consideration. Progress can only be attained with the co-operation of all departments.

The enviable records made by the railroads of today in efficient, economical operation show that the progressive railroad managements recognize the value of soft water for boiler use. The proof of this is in the increased softening facilities installed each year. The progress made in water treatment on the railroads of the United States shows that eliminating costly boiler maintenance is one of the important ways of reducing the cost of operation when the natural water available is unsuitable for boiler use.

OPERATION OF THE NEW WATER SOFTENING PLANT AT SPRINGFIELD, ILLINOIS[1]

By Charles H. Spaulding[2]

During the past thirty-seven years Springfield has developed a ground water supply in an effort to avoid the use of surface water. The development was first by infiltration galleries constructed through coarse gravel at a depth of about 20 feet. Nearly 3000 feet of these tunnels were built, but, as they became inadequate, wells were driven in the glacial drift of the river bottom and the supply augumented by adding more wells from time to time. This combination has usually yielded a fairly potable supply, but not without serious faults. The ground water contained iron in such quantities that meters and service pipes required frequent repairs and replacements, plumbing and laundry were stained and any unusual currents in the distribution system produced roily water at the taps. Moreover the hardness of the water was a source of needless expense to users in causing excessive soap consumption and repairs to water coils, heaters and plumbing in general. Furthermore the ground water required chlorination to reduce the bacterial content to the standard established by the United States Public Health Service. Finally, it became increasingly difficult to obtain sufficient quantity from this source. At the same time the pollution of the Sangamon River increased so that the use of this source without purification became more and more a menace to the health of the city.

A study of these problems over a period of ten years or more led to the construction of a water softening plant capable of handling either surface or ground water.

DESCRIPTION OF PLANT

The raw water is collected in a well 60 feet in diameter by 53 feet deep to which it flows by gravity from the galleries or the river or

[1] Condensed from papers presented before the Iowa Section and the Illinois Section meetings, November 4, 1926, and January 27, 1927.

[2] Chemist and Superintendent, Water Purification, Department of Water, Light and Power, Springfield, Ill.

is pumped from the tubular wells. Low lift pumps deliver the raw water to the dosing well at the end of the head house adjoining the chemical preparation room, where lime and coagulant are added. Thence it passes to two parallel reaction chambers where it is stirred by mechanical agitators revolving at $\frac{3}{5}$ r.p.m. The chambers are 42 feet 8 inches in diameter and the speed of the paddles at the two-thirds point is therefore 0.8 foot per second. The mixing period is 40 minutes at the nominal plant capacity of 12 m.g.d.

From the mixing chambers the water passes through two Dorr clarifiers in parallel, thence through settling basins having carbonating chambers at the outlet ends and finally to eight filter units of the rapid sand type. The detention period in the Dorr clarifiers is one hour and thirty minutes and in the settling basins four hours. The carbonating chambers provide thirty minutes further detention.

The filtered water is chlorinated in the conduit leading from the filter building to a filtered water reservoir of two million gallons capacity.

Equipment for lime handling

One feature of the Springfield plant which has proved very satisfactory is the lime unloading equipment. Quick lime is used because of its lower first cost and higher softening value than hydrated lime. The material is received in bulk and unloaded by means of a vacuum conveyor which lifts it to the third floor of the head house where a screw conveyor distributes it to the three lime bins. With this machine all dust is eliminated around the unloading platform and to a large extent throughout the plant. The task of unloading is reduced to ordinary routine requiring men of no special hardihood or tolerance for lime. The machine best handles pebble lime 1 to 2 inches in diameter containing little fines or dust. However, it will successfully handle ordinary crushed lime providing the size is below 2 inches so that lumps cannot become wedged in the suction line. Smooth clean pebbles roll easily to the suction nozzle while fine or angular pieces require more shoveling. There is no perceptible air slaking during cold weather. In warm weather there is probably some absorption of moisture, but from our experience it is but a fraction of a per cent so that we have not been sure that such difference as we found was not due to errors in sampling. The cost of operating the "Airveyor," as the unloading equipment is called, is 10 to 20 cents per ton, depending on the condition of the lime in the car and

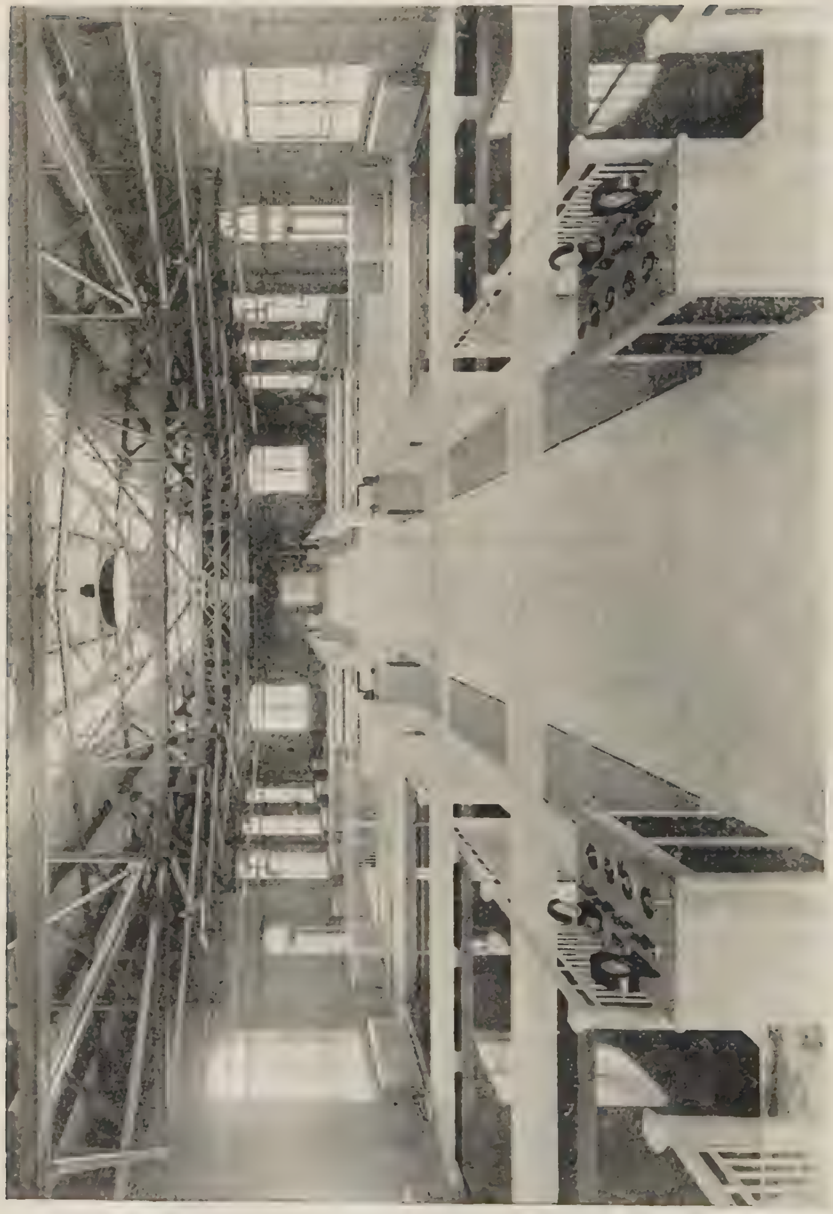

Fig. 1. Interior of Filter House

the amount of shoveling required. The installation was furnished by the Guarantee Construction Company of New York.

Lime from the bins drops by gravity into weighing hoppers and thence into slakers. The original method of handling from this

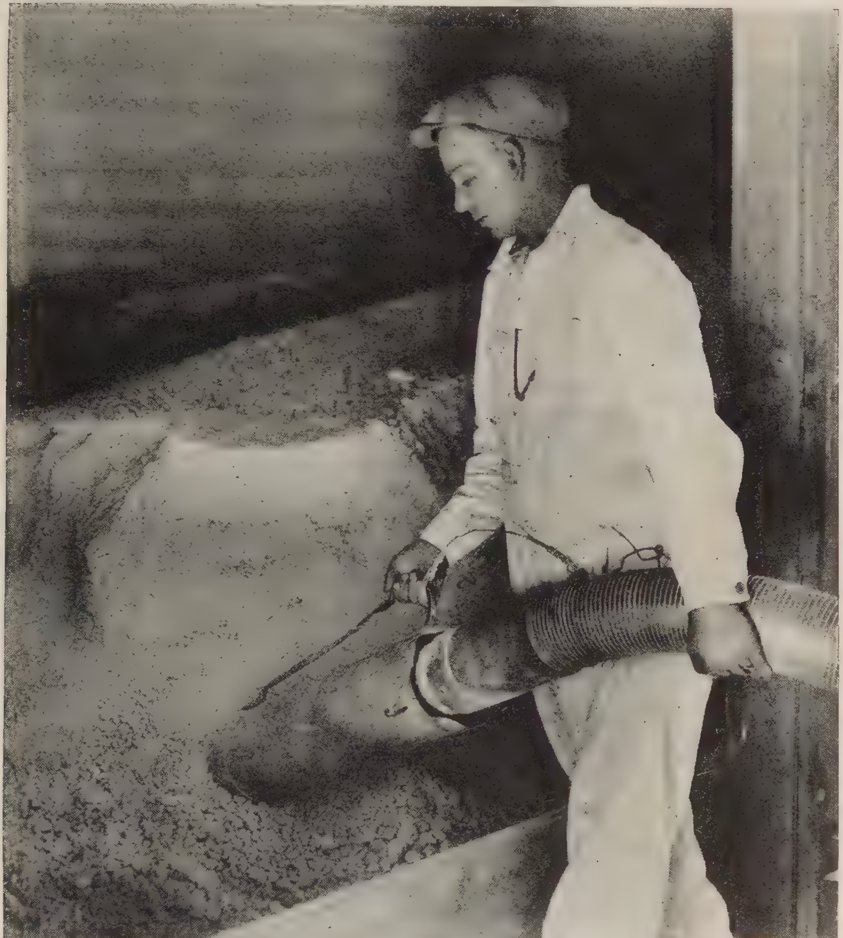

FIG. 2. UNLOADING LIME WITH "AIRVEYOR"

point has been changed and this feature will be explained in some detail.

In the original design the lime suspension was made up in 7000 gallon batch tanks, of which there were three, located in the base-

FIG. 3. HIGH WATER AT PLANT

ment of the head house, one beneath each slaker. The lime was dropped into the batch tanks from the slakers and diluted to the desired strength. Agitating paddles kept the lime in suspension of even strength and a steam jet elevated the liquid to the proportioning machines located over the dosing well. Due to rapid scaling of the discharge line from the steam jets, the jets were replaced by a small centrifugal pump which gave less trouble.

About this time, however, we found that several plants were using dry feeders successfully with pebble lime and we began to investigate the suitability of some such method for this plant. The result of the study was the elimination of feeders, wet or dry, and the proportioning of the lime by hourly weighing into the slaker. A constant stream of water, sufficient to about equal the contents of the slaker once an hour passes through the slaker tank and carries the lime to the dosing well through the gravity line. This eliminates the batch tanks, pumps and measuring machines and greatly simplifies operation.

Several objections to such a method arise. In the first place it would seem that some of the lime might leave the tank unslaked and thus be lost. However, the temperature of the liquid leaving the tank rises and falls in strict accord with the concentration of the lime, which would not be the case if hydration were lagging. It seems likely that unslaked lime remains on the bottom of the tank until hydrated—a matter of minutes, since the water is always warm (35° to 70°C.) due to heat of hydration, no extra heat being required. The lime is all accounted for in the chemical reactions. Another possible objection might be that the water would not be evenly treated, but this is rather an advantage in our case. It may be looked upon as a variation of the method of split treatment proposed and used by C. P. Hoover at Columbus, by which all of the lime is added to half or more of the raw water, adding the balance of the raw water later. The result should be better magnesium removal and a lower hardness in the plant effluent. This effect is obtained as shown in table 1.

Three successive ten-day periods have been compared in which the theoretical lime requirements happen to be nearly identical. In the second period the raw water should require 5 pounds more per million gallons than in the first and in the third period it should require 15 pounds more per million gallons assuming the same magnesium removal in all three periods. The results show the treatment

was nearly as satisfactory in the second period with 53 pounds less per million gallons, while in the third period removals of temporary hardness and magnesium were better by 11 and 10 p.p.m. respectively.

The fluctuation in treatment is in the neighborhood of 100 per cent. This is smoothed out to about 4 per cent at the outlet of the mixing chambers and about 2 per cent leaving the clarifiers. It cannot be detected in the water applied to the filters. The interval of dosing will necessarily depend on the rate at which the plant is operating.

TABLE 1

Comparison of softening results when dosing continuously and periodically

	NOVEMBER 6 TO 15	NOVEMBER 16 TO 25	NOVEMBER 26 TO DECEMBER 5
	Dosing interval		
	Continuous	30 minutes	60 minutes
Raw Water:			
Total alkalinity	238	236	223
Carbon dioxide	25	28	43
Magnesium	113	113	116
Non-carbonate hardness	43	45	56
Filtered water:			
Total alkalinity	59	61	48
Bicarbonate alkalinity	7	21	4
Magnesium	82	79	75
Magnesium removed	31	34	41
Chemicals used, pounds per million gallons:			
Lime, 89 per cent CaO	1,560	1,507	1,577
Aluminum sulphate	44	56	49

Analyses expressed in parts per million of equivalent $CaCO_3$.

The hourly interval which we are using would have to be reduced, if the rate were increased much over 7 m.g.d. At this rate the theoretical detention in the mixing chambers is one hour and six minutes. Actually it takes only thirty minutes for a change in treatment to appear at the mixing chamber outlet.

We have found the accessibility of mechanical mixing chambers is an advantage in cleaning. Quick lime, especially pebble lime, contains considerable quantities of unburned sandy core which settles in the mixing chamber and requires flushing out. The speed of

rotation of the paddles is somewhat too low in our opinion. A sample of water taken at the outlet will show considerable lower alkalinity if shaken a few minutes. Just how much more agitation would be profitable has not been determined as yet, but it is one of the advantages of mechanical agitation that this can be obtained without any limiting conditions of loss of head.

Continuous removal of sludge from clarifiers

A feature of the plant which proved valuable during the recent high water is the continuous removal of sludge from the clarifiers. For a period of six weeks it would have been impossible to drain the basins for cleaning and if sludge storage had been provided for such a period the basins would have required much larger design. Figure 3 shows the plant when the flood was at its crest and conditions at their worst. The clarifiers are removing about 96 per cent of the precipitated solids which amounted to 342 tons during the month of December. The sludge pumps are lifting about 85,000 gallons per day, half of which is returned to the mixing chambers. This sludge, when tested has shown a density of 4 to 10 per cent solids, averaging 5.5 per cent. The water lost with sludge during such a month amounts to about 0.5 per cent of the water treated. If the basins were operated without clarifiers, they would have required emptying and cleaning at least once each month, losing thereby more than twice as much water. Needless to say, the important fact is that the whole basin is available for sedimentation throughout the month with no loss of efficiency due to draining and filling. There is, of course, some sludge depositing in the main basins beyond the clarifiers. In six months of operation it has accumulated to a depth of 4 feet at the inlet end, sloping to 1 foot at half the length of the basins and 2 inches at the outlet end. The basins have a working depth of 14 feet.

PLANT OPERATION DATA

Chemical and bacteriological data on plant operation are briefly summarized in table 2. No very high turbidities have been encountered during this period, but the reduction through the basins and filters has been satisfactory. The filtered water always appears bright and sparkling in the gate chamber of the clear well, even though the turbidimeter shows measurable values.

The sanitary quality of the raw water fluctuates widely, the bacterial load depending on the proportion of river water used. Thus August, the month of greatest daily pumpage, shows the highest counts, especially of B. coli. The B. coli index of the Sangamon River at Springfield from September to January has been over 27,000 per 100 cc. in spite of unusually high dilution from repeated floods. We have reason to believe it will exceed 150,000 per 100 cc.

TABLE 2

Chemical and bacterial results of water purification

	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	AVERAGE
Turbidity, p.p.m.:							
Raw	38.0	64.0	24.0	9.0	6.0	4.0	24.0
Applied	2.0	3.5	3.5	3.0	2.0	2.0	2.6
Filtered	0.3	0.3	0.3	0.2	0.2	0.2	0.25
Hardness, p.p.m.:							
Raw	274.0	232.0	267.0	260.0	279.0	279.0	265.0
Filtered	145.0	92.0	125.0	102.0	106.0	105.0	112.0
Total bacteria per cubic centimeter, 37.5°C., 24 hours:							
Raw	420.0	3,988.0	395.0	321.0	136.0	48.0	885.0
Clarified	106.0	141.0	73.0	13.0	10.8	2.2	58.0
Applied	64.0	58.0	44.0	11.0	6.9	1.5	31.0
Filtered	36.0	22.0	10.0	5.0	3.4	0.9	13.0
Final effluent	13.0	5.0	4.0	2.0	3.6	0.4	5.0
B. coli per 100 cc.:							
Raw	64.0	7,000.0	1,558.0	242.0	136.0	52.0	1,509.0
Clarified	5.0	139.0	49.0	37.0	7.6	1.3	40.0
Applied	11.0	44.0	6.0	8.0	5.7	0	12.5
Filtered	0.0	3.2	1.0	0.7	0.25	0	0.86
Final effluent	0.2	0.2	0	0.2	0.33	0	0.18

at normal summer stages and the bacterial efficiency of the plant is therefore of vital importance.

The outstanding feature of the bacterial data is the high efficiency of the coagulation basins. Here, we believe, is a striking example of the superior efficiency of softening and coagulation over simple coagulation. The average efficiency of the basins as measured by the B. coli index during this period was 99.2 per cent. Compare this with the average of 75 per cent given by the Manual of Water Works Practice. A basin having an efficiency of 99 per cent will

handle twenty-five times the load that can be handled by a basin of 75 per cent efficiency with the same quality of effluent. It should be mentioned that we cannot credit the above performance to excess lime treatment as hydroxide alkalinity was rare during the period and monthly averages were all on the side of bicarbonate alkalinity. We are inclined to attribute the results partly to heavy, voluminous precipitate and partly to the continuous removal of sludge. The efficiency of the clarifiers with only two and one-half to three hours detention shows a removal of more than 97 per cent of B. coli. These results together with filter and chlorination efficiencies indicate that the plant can handle a load of 10,000 B. coli per 100 cc. with considerable margin of safety.

TABLE 3

Operation statistics

	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	AVERAGE
Total water delivered, million gallons	183	252	221	214	203	207	213
Length of filter runs, hours	21.2	24.0	42.4	57.9	66.2	86.9	49.7
Wash water, per cent	3.0	3.1	2.8	1.5	0.9	0.7	2.0
Chemicals used, pound per million gallons:							
Lime	1,500	1,530	1,493	1,330	1,525	1,632	1,502
Aluminum sulphate	131	132	56	27	42	54	74
Chlorine	3.4	2.9	2.8	1.9	0.5	2.3	2.3

Brief operation statistics are shown in table 3. The length of filter runs increased from 21 to 87 hours, averaging about 50 hours. The ratio of wash water to total water filtered averaged 2 per cent, showing a marked decrease during the six months. The increased runs and decreased wash water accompanied a growth of filter sand which has been stopped at this writing by carbonation. Carbonating equipment was not installed during the period covered by this report and is therefore omitted from consideration. In connection with wash water data it may be said that practically all wash water is returned to the dosing well.

Lime used has averaged 1500 pounds per million gallons, the quantity depending on the amount of hardness removed, carbon dioxide and magnesium in the raw water and also the amount of aluminum sulphate required.

No difficulties of serious consequence have developed in the performance of this plant and we feel that all concerned with the design and construction are to be congratulated. The only change of importance has been in the method of lime application, but this is an inovation hardly to have been anticipated.

The operating personnel, in addition to supervision, consists of five men, viz., one operator on each eight-hour shift, one janitor and one relief operator who maintains equipment and unloads all chemicals with the help of the janitor.

The plant was designed by Burns and McDonnell Engineering Company, with the advice of C. P. Hoover as consulting chemist.

SOME NOTES ON SMALL DIESEL ENGINES

By Huldreich Egli[1]

Thirty years have elapsed since the first commercial Diesel Engine (built by the Machinenfabrik, Augsburg, Germany) was put on the open market. The first commercial Diesel engines were of the four cycle air injection stationary type.

At the termination of the Diesel patents, the comparatively few licensed manufacturers had produced engines aggregating over 500,000 horsepower.

While the four and two cycle air injection type engine was developed to a high degree during Dr. Diesel's stay, the inventor's unsuccessful first attempts, the so-called solid or mechanical injection type engine, was perfected later. The Diesel engine soon became a potent factor in the prime mover field. Today, with millions of horsepowers of marine and stationary engines scattered all over the world, there is little need for further introduction of the Diesel principle.

At the termination of the Diesel patents, a number of concerns started to build Diesel engines. While the pioneers were fully aware of the fact that success of Diesel engines involved as much a metallurgical problem as skillful and conscientious design, they manufactured engines at comparatively low piston speeds and with normal load M.E.P. fully capable of taking as much as 30 per cent overload without the engine showing effects of excessive labor or smoky exhaust. Such apparent liberal margins were exceedingly tempting to the less familiar manufacturers. The greater field of uses and competition gave impulse leading to some speculation in the design of the so-called high speed Diesel engine.

Some manufacturers obviously thought that the combustion was the chief problem to solve. This depends upon the type and size of engine, but the ability to withstand punishment of approximately 2900 degrees Fahrenheit, plus pressures ranging between 450 and 600 pounds per square inch at high frequency, has proved even more a perplexing metallurgical problem than ingenuity of design.

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The air injection type of engine lends itself particularly to combustion adjustment, and, if properly adjusted, the overall efficiency is somewhat in favor of the air injection type of engine over the mechanical injection type. The air injection type of engine requires an air compressor, which is a highly specialized piece of machinery, usually built in three stages, forming an integral part of the engine. The air compressor performs several duties. In addition to administering fuel to the working cylinder, make-up air is needed for starting purposes. Since the injection air is depended upon for oxygen to help combustion, considerably more injection air is needed for heavy loads than for light loads. This is obtained by stepping up the injection air pressure at heavy loads, thus necessitating an oversize compressor in respect to normal load requirements. After all starting air is made up, the surplus capacity is regulated either at the compressor or at the injection bottle by means of throttling a purge valve. This operation is a very simple one, but it requires observation. Should the injection air fall entirely too low, serious consequences may be experienced. Automatic appliances to regulate injection air pressure are not particularly recommended. For larger installations, auxiliary air compressor engine units are often used.

The valves of the engine itself need periodic grinding. The frequency depends somewhat upon operating conditions, but requires the judgement of a competent and conscientious operator. Removing and resetting of valves requires checking of clearances. Incompetency or neglect on this part rapidly produces faulty running conditions and break-downs. Exhaust temperatures should be observed and indicating diagrams should be taken from time to time. Lubrication and cooling water are items of special importance. The life of the engine and economical operation largely depend on these.

In the early days of the Diesel engine, it was customary for a purchaser to send a representative to the manufacturer to familiarize himself with the assembly and operation of the respective engine. Such procedure usually proved to be good investment. It is indisputable that the air injection valve operated Diesel engine, with the very features that make this type of engine superior, when not understood can readily be upset. Many break-downs and failures of Diesel engines were directly attributable to ignorance or neglect on the part of the operator. The well constructed Diesel engine in reality does not require much manual work for the attendant, but the engine must be understood and this requires study and alertness.

It may be safely said that most of the Diesel engines manufactured today have benefited from experience gained from earlier blunders.

Today there are Diesel engines suitable for almost any use, but in the selection of the proper type, operating conditions should be carefully weighed. Whereas the user of larger size engines can afford to hire more talented help, the user of medium and smaller type of engines sometimes is handicapped in this respect. Too much attention to fuel consumption guarantees sometimes misleads the purchaser, as such guarantees are based upon properly adjusted engines.

The part played by the human element under which the engine has to perform its daily routine work has been of much concern to many designers and manufacturers. One point may be gained at the sacrifice of another. At times we believe we have succeeded in eliminating trouble, whereas we find we have merely shifted it elsewhere, but, if we succeed in shifting the trouble where it hurts the least, then we have accomplished something.

To reduce the part played by the human element in the operation of the Diesel engine means reducing the number of adjustments and consequently affecting the flexibility of the engine. In so doing, the engine may be somewhat less economical in fuel consumption at various loads, the usual margin for overload may be narrowed and the range of useful fuels may be somewhat restricted. But if reduction of the number of adjustable parts of the engine means more foolproofness, less first cost and less maintenance cost, these merits should more than offset the slight disadvantages.

The mechanical injection type port scavenging engine is a step in the right direction, this type of engine being particularly useful in medium and smaller sizes where fuel used does not vary to great extent and where skill of attendants is at question. In larger sizes of this type of engine, the problem of combustion becomes considerably more pronounced. Therefore, its usefulness so far is limited to moderate sizes.

For larger sizes of engines, the air injection type will most likely prevail. The same may hold good for high speed engines of smaller sizes.

It may be mentioned here that all exhaust outlets of the Diesel engine should be equipped with high grade thermo-couples so arranged that the attendant may readily check the exhaust temperature of each cylinder. An indicator should be included with the sale of the engine.

In addition to the usual guarantees, manufacturers should pledge themselves to analyze indicating diagrams at least twice a year, free of charge, during the natural life of the engine. This may seem to be a harsh demand upon the manufacturer, but a single expert in the organization could take care of thousands of engines per year, rendering real service to the user.

A STUDY OF THE CHLORINE ABSORPTION OF WATER[1]

By Jacob R. Meadow[2] and Harrison Hale[2]

Inasmuch as a greater part of the chlorine absorbed, as indicated by the chlorine absorption test, is used in oxidizing some organic matter and other oxidizable substances in water, it would seem probable that such a test should give values comparable with the oxygen-consumed value (1) which is used as a standard method in determining the capacity of a water to be oxidized, and hence an indicator as to the carbonaceous organic matter it contains.

The purpose of this investigation has been to compare the permanganate method of oxygen consumed in water analysis with that of the chlorine absorption test by different waters. In doing so, it was hoped that a correlation would be found which would permit the use of the amount of the chlorine absorbed by a given water to determine in a large measure its organic content.

The use of the chlorine absorption test has been studied by Wolman and Enslow (2), and the fact that the five-minute chlorine absorption test would compare very favorably with the permanganate test under certain conditions was shown. Their data disclosed a fairly close variation of chlorine absorption with the oxygen-consumed values of different supplies. They found that the five-minute rate of chlorine absorption shows a decreasing acceleration with increases in pollution as measured by an increase in the oxygen-consumed values. Froboese (3) has investigated the capacity of water to decompose hypochlorites and maintains that this determination is of value in addition to its oxygen-consuming power with permanganates. Keiser (4) has recently made a comparative study of the oxidizability of water as measured by the Kubel-Tiemann method and of the determination of the "chlorine number" of Froboese (3). His results are very interesting and will be referred to later.

Before considering the actual data it is best that some of the principles of each of these tests be taken up. The oxygen-consumed

[1] Research paper No. 53, Journal Series, University of Arkansas.

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test (1) was run according to Standard Methods, using 10 cc. $KMnO_4$ in an acid solution at the temperature of boiling water for thirty minutes. It was found in connection with this that an interesting relation exists between the amount of oxygen consumed and the amount of permanganate first added to the sample. This is shown in table 1.

We see from this that the law of mass action is responsible for the gradual increase in oxygen-consumed values with additional amounts of permanganate. We conclude that the 10 cc. of $KMnO_4$ used in Standard Methods is purely an arbitrary amount.

It may be seen from table 2 that mass action applies to chlorine absorption as well.

What then shall be the arbitrary amount of chlorine introduced in the test? This of course makes the "chlorine number" of Froboese (3) or the "chlorine index" of Pecker (5) uncertain and ill-defined

TABLE 1

Relation of oxygen-consumed value to the amount of $KMnO_4$ used in making the test

	SAMPLE	OXYGEN-CONSUMED VALUES, IN PARTS PER MILLION, WITH DIFFERENT AMOUNTS OF PERMANGANATE				
		5 cc. $KMnO_4$	10 cc. $KMnO_4$	15 cc. $KMnO_4$	20 cc. $KMnO_4$	25 cc. $KMnO_4$
1	Tap water	1.25	1.90	2.03	3.14	5.04
2	Spring	2.10	3.02	4.76	6.10	6.30
3	Well	1.06	1.30	1.75	1.96	2.70

unless we know how much chlorine has been added to obtain such a value. One of the problems, then, is to ascertain what amount of chlorine should be added for such a test.

In the hope of finding a better correlation between the chlorine absorption test and the oxygen-consumed method, a wide series of tests was run on numerous samples of potable and non-potable waters. As many tests were made on each sample as was thought necessary to determine any factors which might influence either method. Various amounts of initial chlorine (a standard solution of chlorine water) were used in the chlorine absorption test. One, three, five and ten parts per million of free chlorine were generally used on each sample, the amount of chlorine absorbed being dependent upon the amount added, as would be expected. The ten-minute absorption test, which seemed to be the most feasible one to use, was adopted

and used throughout. The amount of residual chlorine was determined by both the o-tolidine and starch-iodide methods. It has

TABLE 2

A comparison of the results obtained in using the two methods of determining organic content

NUMBER	SAMPLE	OXYGEN CONSUMED	CHLORINE ABSORBED IN TEN MINUTES AFTER ADDING			
			1.0 p.p.m.	3.0 p.p.m.	5.0 p.p.m.	10.0 p.p.m.
		p.p.m.	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*
1	Tap	1.00	0.10	0.30	0.55	0.95
2	Distilled	1.11	0.12	0.33	0.40	
3	Well	1.15	0.22	0.43	0.47	
4	Spring	1.15	0.31		0.88	1.75
5	Spring	1.15	0.40		2.39	4.21
6	Tap	1.20	0.17			
7	Well	1.20	0.16		0.58	0.86
8	Well	1.30	0.28	0.50	0.60	
9	Well	1.35			0.67	0.92
10	Well	1.36	0.26	0.46	0.75	
11	Well	1.40	0.30	0.45	0.66	
12	Well	1.46	0.27		0.54	0.88
13	Spring	1.47	0.32		0.50	0.92
14	Spring	1.60	0.35		0.80	
15	Well	1.66	0.35	0.70	0.92	
16	Well	1.72	0.53	1.51	1.75	
17	Well	1.74	0.48	1.20	1.54	
18	Spring	1.95			0.35	0.60
19	Spring	2.10	0.61		0.94	1.10
20	Well	2.27		1.54	2.75	3.50
21	Well	2.37	0.46		0.72	0.87
22	Well	2.72	0.50		1.25	1.32
23	Spring	3.02	0.51	0.83	1.00	
24	Well	3.33				0.60
25	Well	3.85				1.54
26	Well	3.85	0.50	1.10	1.33	
27	Well	3.88				0.55
28	Well	4.50	0.59		1.30	2.33
29	Well	4.70	0.53		0.90	1.63
30	Well	4.81	0.51		1.49	1.75
31	Well	5.00	0.80	1.70	2.85	3.94
32	Well	7.10	0.90	1.90	2.95	4.30

been shown by Buswell and Boruff (6) that the two tests are equally good in testing for free chlorine. Analyses were run on thirty or

more different samples, using the standard method for determining the oxygen-consumed value. The data regarding the two tests have been compiled in table 2.

Although in a great many instances the two methods are comparable, strict correlation could not be established between them. The amount of chlorine absorbed does not increase in proportion to the increase in the oxygen-consumed value. This is graphically shown in figure 1.

This lack of correlation is probably due in most cases to the fact that it would take more chlorine than was added to equal in parts per million the available oxygen present in 10 cc. of the permanganate. It will be noted that the chlorine absorbed values with 5.0 p.p.m.

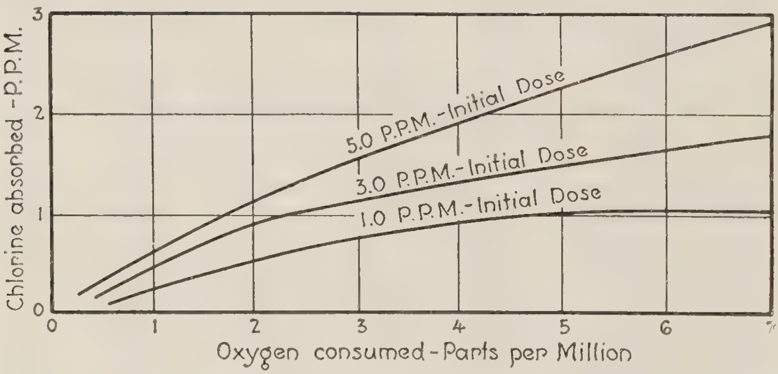

FIG. 1. COMPARISON BETWEEN CHLORINE-ABSORBED AND OXYGEN-CONSUMED RESULTS (AVERAGE VALUES)

and 10.0 p.p.m. vary a great deal and, although in general the values increase, these increases are not proportional to the amounts of chlorine added. It would seem that, if the total organic content of a water is to be determined, even larger amounts of chlorine should be used.

Whether or not the 1.0 p.p.m. value is more indicative of bacterial content than of oxidizable matter is a question. The fact that a water may have a high bacterial count and yet be low in organic content could possibly explain how it may absorb more chlorine in proportion to the amount added with the 1.0 p.p.m. dose than with the 5.0 or 10.0 p.p.m. dose. This happened several times, as seen in table 3.

In studying any other factors to which might be attributed the cause of a wide variation in the results of the two methods, it was noticed that in some cases where the chloride content was exceedingly high the oxygen consumed ran up higher than was expected.

TABLE 3

Oxygen consumed and chlorine absorbed in relation to bacterial count

	SAMPLE	OXYGEN CONSUMED	CHLORINE ABSORBED			AGAR COUNT PER CUBIC CENTIMETER	FERMENTATION (LACTOSE 10 cc.)
			1.0 p.p.m.	5.0 p.p.m.	10.0 p.p.m.		
		p.p.m.					
1	Well	1.35	0.21	0.28	0.50	62	Positive
2	Well	1.40	0.30	0.45	0.66	10	Positive
3	Spring	1.47	0.32	0.50	0.92	100	Positive
4	Spring	1.95	0.28	0.35	0.60	400	Positive
5	Well	4.70	0.52	0.90	1.63	2000	Positive

TABLE 4

Oxygen consumed and chlorine absorbed in relation to alkalinity and to chlorides

	SAMPLE	OXYGEN CONSUMED	CHLORINE ABSORBED			ALKALINITY WITH M. O.	CHLORIDES
			1.0 p.p.m.	5.0 p.p.m.	10.0 p.p.m.		
		p.p.m.				*p.p.m.*	*p.p.m.*
1	Well*	1.35	0.21	0.28	0.50	3.1	Trace
2	Well*	1.46	0.20	0.44	0.85	4.0	Trace
3	Spring	1.15	0.40	2.39	4.21	177.0	42.5
4	Spring	2.10	0.61	0.95	1.10	128.0	12.5
5	Well	2.27	0.78	2.75	3.50	191.6	51.0
6	Well	2.72	0.50	1.25	1.32	68.0	10.0
7	Well	2.37	0.46	0.72	0.87	98.0	228.56
8	Well	4.50	0.58	1.30	2.30	105.0	102.58
9	Well	4.70	0.52	0.90	1.63	47.2	256.0

* Low in both alkalinity and chlorides.

On the other hand, some waters high in alkalinity absorbed an unusual amount of chlorine. These facts are shown in table 4.

This might be explained by the fact that more of the available oxygen is used in oxidizing the large amount of chlorides present. A water high in alkalinity might absorb more chlorine in the formation of certain hypochlorites.

In connection with the work which has been done, many data of interest have been gathered from Keiser's paper (4) in which he makes a comparative study of the two methods on raw Elbe water and the filtered water at Hamburg. Keiser's work was found in the literature after the investigation here had begun. His data might explain some of the variations observed here in comparing the two tests. A study of these results shows that, for the determination of organic matter in water free from albuminous products, the permanganate process according to Kubel and the determination of the chlorine number of Froboese are equally good; on the other hand the content of organic matter in water which has been polluted with sewage, can be exactly fixed only by means of the chlorine absorption test.

TABLE 5

Effect of urine content on oxygen-consumed and on chlorine absorbed

URINE CONTENT	OXYGEN CONSUMED	CHLORINE ABSORBED (10.0 P.P.M. ADDED)
mgm. per liter	*p.p.m.*	*p.p.m.*
Tap water	1.30	0.32
1	1.35	0.40
3	1.38	0.72
5	1.33	0.80
10	1.36	0.85
50	1.42	1.15
100	1.45	1.59
250	1.96	2.51

In confirmation of Keiser's work, the data indicated in table 5 show the results carried out here with increasing amounts of urine in tap water. The chlorine-absorbed and oxygen-consumed values were noted.

It is indicated here that albuminous products like urine are not readily attacked by permanganate, so it would seem that the determination of the oxygen-consumed value is inaccurate under such conditions.

According to all the data shown herein, the correlation between the two methods is good as long as no albuminous material is present. In the latter case the chlorine absorption test is the only safe criterion. In view of these facts the chlorine absorption method should be in all cases an equally desirable one to use and, in certain cases, it

certainly would be preferable. It seems entirely reasonable that a standard method of procedure should be established wherein the quicker ten-minute chlorine absorption test would be used as a substitute for, or at least a companion test with, the slower permanganate method of determining oxygen consumed.

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WATER PURIFICATION[1]

By Paul Hansen[2]

A paper on water purification for municipal purposes written fifteen years or more ago would have dwelt at length on the benefits of purification and would have had much to say about the losses from sickness and death that can be prevented by water purification. It would also have translated the losses from sickness and death into dollars and cents, as it was generally assumed that this would make the most urgent appeal to public consciousness.

All that has changed, and today water purification is established and accepted. Health must be protected as a matter of course and higher and higher demands are being made as to physical and chemical characteristics of water supplied to the consumers. The change can best be explained by saying that the public has learned to want better water. Probably this education has come about principally through the force of example of those cities that were among the first to install water purification works. At this point there entered as a factor a degree of municipal pride which caused the public to feel that its reputation was at stake so long as muddy water was pumped into the mains. In the final analyses, however, it is a development in the public mind of an appreciation of and a demand for a better product.

Along with this installation of water purification works, there has developed a demand for constantly increasing standards of quality, so that many water supplies which ten or twenty years ago were regarded as fully satisfactory are not so regarded at the present time. All cities with untreated water supplies which do not meet present day standards know that they must, sooner or later, install water purification works and it is primarily a matter of deciding upon the best plan and of arranging necessary finances.

In the light of the foregoing, it seems more appropriate to devote this discussion to advances and present limitations in the art of water

[1] Presented before the Canadian Section meeting, March 3, 1927.

[2] Of Pearse, Greeley & Hansen, Engineers, Chicago, Ill.

purification than to an argument in favor of the application of water purification. In speaking of water *purification*, filtration should be understood as constituting the main element in the process. Disinfection of water with liquid chlorine or by other means should be preferably referred to as *treatment*, inasmuch as its sole function is to remove organisms of disease. It does not improve the physical or chemical characteristics of the water, but rather it makes them worse. Moreover, the disinfection of unfiltered water is fraught with so many difficulties and uncertainties that it should be looked upon usually as an emergency, rather than as a permanent, method of water treatment. Sterilization as an adjunct to filtration is fixed and accepted and will be discussed later. Removal from water of minerals causing hardness and also the removal of iron and manganese which cause discoloration in water are also forms of water purification but these can be touched but lightly at the present time as each constitutes in itself a rather large intricate field or water treatment.

STANDARDS FOR FILTRATION PLANT PERFORMANCE

The most important development in connection with water purification practice which has taken place during the past quarter of a century is the increasing standard for measuring the performance of water purification works. In 1900 a reduction in bacterial content of 97 per cent (as determined by plating on nutrient gelatine at 20°C.) was regarded as adequate. Many of the filter plants of the country were installed by filter companies and they usually made guarantees of 97 per cent removal, provided the bacteria in the raw water were not less than 1000 per cubic centimeter. If less, then it was agreed that the number of bacteria in the filtered water should not exceed 100 per cubic centimeter. At a later period, efficiencies of 98 per cent were regarded as necessary and a maximum of 50 bacteria in the filtered water per cubic centimeter was set as a proper limit. There was also much discussion as to whether any analytical standards could be adopted. Many engineers and analysts maintained that epidemiological evidence constituted the only reliable guide and that any analytical data must be interpreted in the light of local circumstances. In 1911 and 1912 a committee was appointed by the United States Public Health Service to agree upon standards of analyses for drinking water used on inter-state carriers. This committee worked for three years before an agreement could be reached. However, the committee finally decided upon the now more or less familiar "Old"

Treasury Standard for drinking water on inter-state carriers. There was a great deal of opposition to the acceptance of this Treasury Standard as a measure of performance of filter plants. It became obvious, however, that with disinfection with liquid chlorine as an adjunct to filtration, this standard of purity was an attainable one and, inasmuch as high standards are in the direction of greater safety, it became generally accepted. In 1925 the Treasury Standard was revised. Although made somewhat stricter, it permits more latitude in variations in individual samples than did the Old Standard. It is now required that not more than 10 per cent of samples shall give positive presumptive tests for the colon bacillus in 10 cc. portions, equivalent to a coli index of 1 per 100 cc.

RAW WATER LIMITS

Another interesting development with reference to units of measure in connection with the performance of purification works is the consideration that has been given to the limit of pollution of raw water. This matter was first taken up by the International Joint Commission on Boundary Waters between the United States and Canada. The experts who were engaged by this Commission came to the conclusion, on the basis of the evidence available in the Great Lakes basin, that a raw water in order to be amenable to treatment by established and standard methods of water purification should not contain more than 500 colon bacilli per 100 cc. The limit of pollution was predicated on the purified water meeting the Old Treasury Department Standards.

In 1922 H. W. Streeter of the United States Public Health Service made a statistical study of the performance of twenty-five water purification plants in the central west on the basis of data previously collected by Jack Hinman and presented in The Journal for September, 1918. On the basis of relations thus established it appeared that the average efficiency of modern filter plants of the rapid sand type, supplemented by chlorination, is such that, in order to obtain a purified water complying with the Old United States Treasury Standard for purity of drinking water on inter-state carriers, namely a colon bacillus content of 2 per 100 cc., the raw water should not have an average colon bacillus content of more than 650 per 100 cc.

In 1923 Streeter made elaborate comparative studies of the performance of ten filter plants taking water from the Ohio River and confirmed his former studies showing a definite relation between raw

water bacterial content and filtered water bacterial content. At the plants studied, however, chlorination of the filtered water was necessary to secure a final effluent that would meet the Old Treasury Standard when the raw water contained colon bacilli to the extent of 100 per 100 cc. and even less. Where chlorination was used, filter plants with double coagulation and double sedimentation could adequately purify waters containing as many as 10,000 colon bacilli per 100 cc., while plants with single coagulation and sedimentation could successfully handle waters having materially in excess of 1000 colon bacilli per 100 cc.

Further studies on an experimental filter plant at Cincinnati have verified these findings and have indicated 100 colon bacilli per 100 cc. as the limit of raw water pollution where filtration alone is employed.

FURTHER AIDS TO CONTROL

Although not related directly to the measure of results obtained by water purification works, practical methods for the determination of hydrogen-ion concentration in water have proved very helpful in securing effective and economical application of coagulants.

Another aid to the control of a filtration plant is the microscopic examination of sand grains as developed by Baylis at Baltimore. The effectiveness of filtration and the general behavior of sand beds is intimately related to the thickness and character of organic coating surrounding sand grains. Experience in examining sand grains will indicate when corrective measures are required to prevent excessive cracking of sand beds and to prevent the formation of mud balls.

New methods of recording the sizes of sand grains in rapid sand filters are coming into vogue notably at St. Louis and Baltimore. Instead of considering the sand bed as a mass, it is considered as composed of layers and the size and uniformity of sand grains in each layer is considered. Further study of the performance of rapid sand filters, with reference to the stratification of the sand bed, should throw more light on the character and thickness of sand required to obtain best results. Present practice is based largely on precedent and generally accepted experience rather than on a close analysis of the functioning of the sand bed.

During the past ten years great improvement has been made in the general arrangement of filter plants with reference to ease of operation, accessibility of parts for repair, light and practical beautification.

The buildings and interior finish of filter plants is becoming comparable to the best pumping station practice. Some of the newest filters, notably the new Baldwin Filtration Works at Cleveland are veritable temples to pure water.

APPLICATION OF CHEMICALS

With reference to the preparation and feed of chemicals little notable advance has been made. There has been a tendency toward dry feed machines in preference to wet feed. In some cases, notably at Indianapolis, ingenious hydrometric devices have been developed for maintaining a solution of constant strength that may be fed into the water at rates proportional to the volume of water being delivered to the plant. Inasmuch as filter plants are usually operated at a fairly uniform rate, these elaborations have not been found altogether necessary. With small clear water storage these devices may prove valuable especially when operated in conjunction with master filter rate controllers. There are a number of dry feed machines on the market which now give good results. The early machines were troublesome, partly on account of clogging and caking of the chemicals and partly because they were not built sufficiently rugged. At Wheeling, West Virginia, there has recently been installed a machine for slaking and feeding lime which is economical of space and cleaner than the usual methods.

Much thought has been given to the design of mixing chambers for the purpose of mixing the chemicals intimately with the water to be treated, but there still remains more or less divergence of opinion as to the best design and capacity for these chambers. The tendency is toward a vigorous mixture immediately following the application of the chemical, followed by a gentle mixing for a more or less prolonged period. Some are inclined to believe that, if a thorough mixing is obtained promptly following the application of a coagulant, further mixing is unnecessary. This seems to be borne out by the behavior of the coagulant in some plants where complete precipitation does not take place until long after the water has passed out of the mixing chambers. Various methods are used for mixing the water such as baffles, stirring devices or a waterfall, exemplified in the hydraulic jump. Further study on this important item is desirable as there is at present a rather wide divergence in the design of reaction chambers.

SEDIMENTATION BASINS

Although sedimentation has long been regarded as an important part of rapid sand filters, the principles upon which sedimentation basins should be designed have never been adequately applied in practice. It is generally assumed in modern practice that a retention period in sedimentation basins of two hours represents a minimum and that more is desirable depending upon the amount of turbidity carried by the water. There seem to be other factors that should enter into a consideration of the size of sedimentation basins, including the time required for precipitation of chemicals under adverse conditions and the treatment of raw water with chlorine when split chlorination is used or when super chlorination is deemed advisable for killing troublesome organisms or overcoming phenol tastes. Although Hazen, in 1904, laid down some important principles in regard to the design of sedimentation basins, these have not generally been regarded. The controlling elements in actual practive are primarily economy of shape and ease of construction. This generally results in the installation of basins much deeper than is necessary for storage of settled solids and for producing most favorable sedimentation.

Withing the last few years much attention has been given to the use of mechanical devices for continuously cleaning sedimentation basins used for waters carrying excessive turbidities. Such basins are being incorporated in the new works at Kansas City. Basins of this type may be used before or after the application of the chemical coagulant.

Very favorable results have been noted in the Ohio River valley as a result of the use of double coagulation and double sedimentation. This not only makes it possible to handle more pollution, as already indicated, but also improves the economy of chemical application.

FILTER UNITS

There has been comparatively little change in the design of the filter units themselves. Units built during the past year have not differed essentially in size or arrangement from those built twenty-five years ago at Little Falls, New Jersey. Principal attention has been given to the underdrain system. Within the past few years a number of new devices have been proposed. Gore of Toronto has effectively prevented the shifting of the gravel bed by mixing the

upper layers of the gravel with a thin cement so as to form a porous slab. This idea has been extended further by Jenks in Sacramento, who proposes a strainer system consisting of vitrified pipe imbedded in gravel held together with thin cement in the manner used by Gore. Experimental results on the Jenks type of filter bottom are very favorable. They would probably give trouble, however, if used in connection with a water softening plant or a plant in which lime and iron are used as coagulants on account of the tendency of the material to clog with deposits of lime. Delerey of New Orleans has patented the use of brass tube laterals of relatively large size and perforated with a special type of opening which tends to neutralize the effect of velocity head in forcing the larger portion of the water to the outer ends of the laterals. Several of the filter companies have gotten out various schemes for cement block underdrain systems one of which uses glass tubes for openings. At Baltimore wooden slat underdrains have been tried and seem to give successful results. Most of the efforts in connection with the design of underdrains have been toward economy rather than improvement in the functioning of the underdrains, inasmuch as it has been found in practice that a properly designed system of underdrains consisting of a grid of piping with perforations on the underside of the lateral piping gives reasonably good results in the distribution of wash water. The most conspicuous change over earlier practice is the virtual abandonment of brass strainer heads. Twenty years ago every filter company had its own design of strainer. Some engineers also designed special strainers. These gave a great deal of trouble by wearing out, due to the abrasion of sand and often the threads which attached them to the lateral pipes became corroded so that they were blown out resulting in very bad distribution of wash water and much sand getting into the effluent piping.

Filter units are built in a number of sizes, the most usual encountered in practice being one-half million gallon units, one million gallon units, two million gallon units and four million gallon units. Occasionally there are odd sizes. The variation in size is somewhat controlled by the variation in size of standard piping and valves. Four to six million gallon units are generally accepted as the maximum size units practicable. It may be possible to build larger units, but they would be of questionable economy because of increasing elaboration in the design of the underdrain system and wash water troughs for the purpose of getting equal distribution of wash water.

CLEAR WATER BASINS

Clear water storage reservoirs have changed but little in design. It has been universally accepted that they must be covered to prevent accidental or malicious pollution and the direct entrance of sunlight which promotes the development of chlorophyll bearing plants. Little uniformity of practice exists in determining the size of clear water storage. It has varied over a wide range. More recently, especially in connection with the larger installations, more thought has been given to an economical and workable balance between filter capacity and clear water storage capacity. There are a number of factors that enter into a consideration of a proper relation between clear water storage and filter capacity. An economical balance between filter capacity and clear water storage may be arrived at on the following basis. The filter capacity is generally made sufficient when operating at maximum rates (anywhere from $1\frac{1}{4}$ to $1\frac{1}{2}$ times normal rates) to yield the quantity of water anticipated on a maximum day likely to occur in the last year of the period for which the plant is designed. Either storage or additional filter capacity is required to meet the differential between a variable rate of consumption and a uniform rate of filtration throughout the twenty-four hours, plus an added quantity for washing filters and a sufficient reserve to meet reasonable fire demands. The quantity of water required for neutralizing the differential between the variable rate of consumption and the uniform rate of filtration can be determined by means of a mass diagram. Curves showing the cost of storage of various capacities and additional filter capacities can be drawn in such a way as to show the economical balance. A decision cannot be made on the basis of economy alone, but an analysis as above outlined furnishes a valuable guide to judgment. It is quite important to consider convenience of operation. If there is but very little clear water storage and large filter capacity, it will be necessary to vary the rate of delivery of raw water at frequent intervals during a day of maximum or nearly maximum consumption. If the raw water must be pumped, this requires increased pumping capacity and a larger number of units with attendant bother in operation. Some inconvenience also results in the application of chemicals, to meet varying numbers of filters in service, but this can in large part be overcome by automatic devices already referred to.

If an elevation is available upon which reservoirs may be cheaply

placed and connected with the distribution system, additional storage may be economical and desirable to improve high lift pumping conditions. Large storage on the distribution system is particularly valuable when pumping is done by purchased electrical energy. Under this condition the pumps can operate at their maximum efficiency, the demand charges for electricity are cut down and standby equipment using an independent source of power may be maintained at a minimum or even omitted altogether.

AERATION

Aeration has been extensively used as an adjunct to filtration, usually preceding the application of chemicals. In recent years consideration has been given to aeration following filtration as a means of eliminating carbon dioxide and any tastes and odors that may have escaped preliminary aeration and filtration. A variety of aerators have been used, some involving an arrangement whereby the water can fall over a series of steps, others using spray nozzles similar to those for cooling condenser water and still others using diffused air either blown into the water or entrained in some manner. Nozzles are most favored, although these require a considerable pressure of water to make them function properly. Nozzle design has been improved in the past year or two so as to minimize the head necessary to secure a good spraying of the water. Aeration is found very effective in removing certain forms of tastes and odors, more particularly those resulting from microörganisms. At Whiting, Indiana, the aerators were found effective in removing odors due to oily wastes from oil refineries, but were not effective in removing phenol tastes and odors. Aeration is applied to ground water for removing hydrogen sulphide and for oxidizing and precipitating iron in solution.

DISINFECTION

Chemical treatment of water for various purposes has been given much thought in recent years. The outstanding chemical treatment is by means of chlorine. Ten to fifteen years ago disinfection was effected primarily with calcium hypochlorite rather than with chlorine. The application of liquid chlorine was introduced by Darnall in 1910. Apparatus for applying liquid chlorine or chlorine gas has been constantly improved by manufacturers, so that chlorine application can now be readily adapted to meet almost any needs.

Chlorine may also be used effectively for reducing tastes and odors, notably phenol tastes. In order to accomplish this, super-chlorination is required, that is, to say a dose of chlorine much larger than that required for sterilization must be used and one which results in imparting a marked chlorine taste and odor. This excess chlorine must be neutralized and for this purpose sulphur dioxide in cylinders has been found the most practicable and effective as used by Howard at Toronto. Thiosulphate and potassium permanganate can also be used to neutralize excess chlorine, but these chemicals are more expensive. Filters sometimes give trouble, especially in iron removal plants due to clogging with organisms—more particularly crenothrix. Not only does crenothrix clog the filters, but it also creates objectionable tastes in the water. Pre-treatment with chlorine has been found effective in combatting crenothrix. Its success with other organisms has thus far not been so pronounced, although Hale accomplished notable results in treating the Croton water supplying New York City. The waters of Lake Michigan and other great lakes are particularly troublesome at certain times due to the presence of large numbers of microörganisms. These organisms are apt to occur when the water is most clear and in mid-summer. In some places, notably at Evanston and Winnetka, Illinois, organisms have been known to clog filters, thereby reducing filter runs to two or three hours. Opportunity has not yet presented itself for an effective test of chlorine in combating this difficulty.

Pre-treatment with chlorine, or so called split chlorination has also been found effective in reducing the amount of coagulant required. The nature of this action is not entirely clear, but has been observed at several plants, notably at Rensselaer as reported by Cox. The use of ammonia with chlorine or hypochlorites to produce chloramine as introduced by Race at Ottawa is receiving new attention as a means of combatting or avoiding residual chlorine tastes.

OTHER CHEMICAL TREATMENT

The use of lime and soda ash and zeolites for softening water will not be discussed in this paper. It may be well to note in passing, however, that the use of carbon dioxide usually generated at the purification plant is used for treating the softened water so as to remove mono-carbonates which tend to encrust sand grains and deposit in the distribution mains. Back treatment with carbon dioxide is also advantageous at plants not primarily devoted to water soften-

ing, but where lime and sulphate of iron are used as coagulating chemicals.

Corrosive qualities of water have been given considerable attention in the last few years. Filtered water in connection with which alum is used as a coagulant is apt to contain excess of carbon dioxide and oxygen which tends to tuberculate and corrode piping, especially hot water piping. This difficulty is being met in part, as already noted, by aeration following filtration and in part by lime treatment following filtration. Lime treatment need not be carried on continuously, but merely until a protecting coating has been formed in the distributing piping. This coating requires renewal from time to time. Lime treatment for this purpose has recently been instituted at Centralia, Illinois with marked success. Use of sodium aluminate as a coagulant also has a distinct advantage in eliminating the corrosive qualities of filtered water and favors quick flocculation.

MEASURING AND INDICATING DEVICES

Filter plant control has been improved by more complete measuring and indicating devices than were formerly customary. In plants of larger size, it is usual to meter the raw, the filtered and the wash waters. Large dials readily seen from any part of the plant as used at Buffalo are helpful in enabling the attendants to observe the rate of flow of water. Individual filters are equipped not only with indicating loss of head gages and indicating flow gages, but also with recording equipment so that charts may be maintained of the daily performance of every filter unit.

DETERIORATION OF CONCRETE

When reinforced concrete filter plants were first built, there did not exist an appreciation of the tendency of concrete to disintegrate in contact with water due to leaching out of soluble matters supplemented by frost action. This action has been aptly termed by Bayliss the "corrosion of concrete" and is a phenomenon observed most frequently at and above the water line, although as at Baltimore and elsewhere it has been known to take place below the water line. The principal cause of disintegration of concrete is apparently porosity. Porosity is particularly destructive of walls holding water on one side and exposed to frost action on the opposite side. Such walls are frequently used in connection with filtration plants. Within re-

cent years a realization has come about of the importance of securing the densest possible concrete and this can best be accomplished by maintaining a proper cement water ratio. Many engineers now specify cement water ratio mix for concrete for all classes of concrete. This was done in connection with a recently completed reservoir for the Indianapolis Water Company at Indianapolis and proved to be entirely practicable and successful. To avoid further the disintegration of concrete, consideration is being actively given to the use of waterproofing compounds. These compounds are not used primarily for the purpose of making reservoirs water tight, but are applied at and above the water level in order to provide a surface impermeable to water.

INCREASING RAW WATER LOADS

Although not within the category of water purification, the question of sewage treatment as a means of preventing too great a burden on water purification works has recently been more or less discussed. It is undoubtedly a question which will become more and more prominent in the near future. Needless to say, sewage treatment of any type cannot be regarded as a substitute for water purification, not only because it would be ineffective as such, but because sewage treatment costs more than water purification per capita. The most logical and equitable manner of approaching this question is not entirely clear. There is at present a tendency to demand that degree of purification of sewage which will maintain the water in a stream at points where it may be used for water supply within the tentative limit of pollution established by the International Joint Commission on the Pollution of Boundary Waters, and by the United States Public Health Service, namely a maximum of 500 colon bacilli per 100 cc. of water. It may be found impracticable and prohibitively expensive in some cases, especially below very large cities, to maintain such a degree of purity in waters, nor may such a degree of purity be necessary to meet other requirements of sewage disposal. To meet situations of this sort it may be necessary to envisage the possibility of more water purification. The studies of Streeter along the Ohio River indicate that an elaboration of water purification works may effectively meet added pollution. For example, a water purification plant comprising double coagulation, double sedimentation, rapid sand filtration followed by slow sand filtration, split or super-chlorination and other accessories may readily purify water containing

50,000 and more colon bacilli per 100 cc. This suggests the possibility that slow sand filtration may be revived as a secondary process to rapid sand filtration for which it would be peculiarly well adapted. It is actually being used in this manner in several places, notably at Poughkeepsie and Albany, New York. Double filtration is also used at Montreal, but not in the same manner as here suggested, inasmuch as the rapid sand filters at Montreal are not preceded by coagulation and sedimentation. The limit to which water purification can be carried is not entirely clear. It is probable that before pollution reaches the limit of what an elaboration of water purification processes can effectively handle, the aesthetic sense of the water users will rebel and demand either more sewage treatment or the development of a source of supply less subject to contamination. This latter alternative is exemplified in the case of Albany, which, after establishing a plant comprising an unusual elaboration of water purification devices, is now seeking at large expense a water less subject to pollution than is the Hudson River below Troy.

It would seem desirable, where practicable, to correlate sewage treatment and water purification along a given stream. Generally, this is not practicable as municipalities are not disposed to purify sewage at great expense in order to protect water supplies below, unless forced to do so through legal pressure. There has recently been created in Illinois machinery for handling such a situation in the form of a Conservancy District Act, under which water supply and sewage disposal may be placed under the control of a central authority for an entire river basin or any portion thereof. Lake cities which pollute their own water supply with their own sewage have the opportunity of working out an economical balance between water purification and sewage treatment. It often happens, however, that matters other than water supply, namely, the prevention of nuisance and the protection of bathing beaches, determine the necessary degree of sewage treatment. However, the opportunity does exist in a number of instances and is worthy of much thought and investigation on the part of sanitary engineers. In the North Shore Sanitary District of Illinois, for example, the most economical sewage treatment for the protection of water supplies and bathing beaches has been found to be sedimentation followed by chlorination. These plants are relatively small in size and a quite different solution might be required where large volumes of sewage are being dealt with.

In conclusion, it is desirable to point out that, notwithstanding the

relatively wide field for the further development and perfection of water purification processes, the art of water purification has long been developed to the point where water purification problems of cities may be solved with economy and absolute assurance that the results will be satisfactory. The further development of the art relates primarily to refinements in control, to perfection of construction details, to the better use of construction material, to broadening the field of applicability of water purification processes and to the co-ordination of sewage treatment and water purification.

DRAMATIZING WATER WORKS REPORTS[1]

By J. R. Cortese[2]

Some water works superintendents, and occasionally city officials, may question the value of a water works report and doubt if its cost is money well spent. The answer to this question is simple. It depends upon the report.

One of my favorite indoor sports is to examine water works reports: the good ones being read with much interest and filed for frequent reference.

Water works reports reflect exactly what the superintendent or manager is. Invariably a good superintendent issues a good report. When one examines, as I have recently, a report that contained page after page of fire hydrant locations, and another report where pages were devoted to statistics fifteen to twenty years old, it does not require an efficiency expert to figure out the loss and waste of time and money by issuing such a document. The printer's proof reader was probably the only person who read the entire document. My criticism of water works reports comes from reading them and, therefore, from the standpoint of the consumer, I am going to mention briefly a few features of reports that have made them especially interesting to me.

WHY SHOULD A REPORT BE MADE?

A water plant is one of the chief assets of a city; in value it ranks well towards the top of all the city investments, whether owned by the city or company. The success and continued operation of all other industries, factories, etc., are dependent entirely upon the water works. The health, growth and prosperity of the city are entirely dependent upon the purity and cleanliness of its water supply. Its customers extend over the entire city; its commodity is standardized and is of one quality. If the city owns the enterprise, every citizen of the town is a stockholder and, therefore, a report to the public

[1] Presented before the Montana Section meeting, January 8, 1927.

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is due; and the public, further, has a right to demand a real water works report in keeping with the importance of the utility.

APPEARANCE OF REPORT

Reports, like people, are often judged by appearances and, therefor, it should have an attractive cover and be of a good quality of paper and printing. Like a girl's skirt, it should be long enough to cover the subject, yet short enough to be interesting. The pictures accompanying a magazine article always produce a desire to read the article and photographs and cuts should be freely used to relieve the monotony in text statistics.

WHAT IT SHOULD CONTAIN

A brief historical sketch, giving date of purchase or date when built and the present value of the property, is always of interest to new customers.

Statistics themselves are rarely read by the layman and these should be converted into graphical diagrams, which are understood at a glance.

A concise tabulation of operating costs, annual revenue, fuel costs, increase in number of connections, etc., shown both by figures and graphical charts, are always interesting and these should not cover more than a ten-year period, as old statistics are of little interest or value.

A population curve and water consumption curve are always well worth the making, as it shows what future provision for growth should be made.

A plain statement from health authorities regarding purity of water, with percentage of bacteria removed, with cuts or illustrations of bacterial comparison of raw water and treated water, is the best kind of advertising a report can contain, for one must not forget that his business is selling water and the reports help sell the customer. People always like to know how their money is spent and a graphical diagram showing what part of a dollar goes for interest, labor, fuel and operation, is enlightening.

Illustrations showing losses by leaky faucets, bad plumbing and unregulated flush tanks for sewers, are helpful in bringing about reforms. Such illustrations are convincing in showing customers how much their own bills could be reduced by eliminating all wastage.

The reduced pumpage, fuel or power bills and increased revenue by a universal meter system are features that can and should be shown in every water works report, for even in this enlightened day we find a few communities who still sell, or rather give water away, without meter measurement. Our city of Livingston happens to be one of them, but we hope that within a year or two we will be metered.

The city, corporation or individual does not exist that can make a success of selling any commodity without measurement of the amount sold. The report should show, or account for, the loss between water delivered and water sold, and if this does not show a yearly improvement, something is radically wrong and needs correction.

A water works plant is never finished or completed and the needed extensions, betterments and improvements ought always to be prominently shown in a report, then there are no shocks or surprises. If bonds are needed there is nothing gained by concealing the fact. Show in the report why the improvements are needed and what advantages and results will be gained by them.

Every report ought to show the cost of delivering water per 1000 gallons, including interest, depreciation, sinking fund reserves, etc. This information is not always known by the superintendent himself and when he figures it out, he will, in many towns, find that large users, railroads especially, are getting their water at less than its cost of production. When one glances at his own railroad and Pullman expenses these times, it causes the reflection that railroads ought to have sufficient funds available at least to pay for the cost of furnishing water. In these days of regulation of rates, one cardinal law acknowledged by all is that the rates of each utility, whether a water plant, light plant, or railroad, should be based on its value and cost of operation. The railroads or other large users are not institutions, with rates made because of their being a special aid or help to a town. Every report should show what the rates should be to earn this interest, depreciation and operating expenses.

VALUE OF A REPORT

A report is of much advertising value to the entire community, so much so that many commercial clubs are joining in the expense of printing and circulating water works reports. Every live water works superintendent knows the advertising value himself of getting out a good report. It places him in a favorite light before many other communities where opportunities for advancement exist.

The educational value is of greatest importance. It acts as an aid in getting bonds for needed improvements, as a basis for argument for equalizing rates or in securing a raise of rates.

HOW PRESENTED

A report to be of any value must be interesting, for if not interesting it will never be read. The author of the report or some water works official should personally present a resume of his report before every civic organization of the town, not omitting the women's clubs. These reports, thus presented, keep before the public a keen interest in their own utilities. Extracts from reports are desired by the local papers and should be given to them. Exchange your reports with the official of other cities of your state.

The water works plant is the chief asset of the city, but the lack of general knowledge concerning it is a fault we can largely correct by getting out and presenting a genuinely interesting report. Whether it pays or not depends on the report and its presentation.

WATER RATES[1]

By J. Clark Keith[2]

The average citizen pays less than one cent per day for practically an unlimited supply of water. From the waterworks department he secures the cheapest service rendered by any public utility, while at the same time immediate and insistent complaint arises if the service is suspended even momentarily. It is rather taken for granted that interruptions in electrical or gas service may arise from time to time and little, if any, comment is made, but a waterworks distributing station is expected to be the nearest approach to perpetual motion that has yet been devised.

The growth of any water supplying organization, either municipal or private, is dependent upon and presumably keeps pace with the municipal demand. From humble beginnings it extends its service where and as required and, like all other businesses, the service which it can render is dependent upon the return secured for that service. The method of obtaining revenue is as peculiar to each community as is the design of its pumping station or the layout of the distribution system. Rates which would create a surplus in one community would be disastrous in another, with conditions seemingly parallel. In dealing with public utility corporations, the courts have excluded evidence tending to prove the worth of the service to the users, by a comparison of the existing rates with the charges for similar service in other communities. This is based on the fact that identical plants rarely exist in two places and weight cannot be given readily or intelligently to the different causes which tend to make the cost of the service, or worth of the service, more in one plant than in another. Under equally efficient management, there is a definite reason why water in one community costs more or less than in another which appears similar and the price of service is not susceptible to yardstick measurement.

[1] Presented before the Canadian Section meeting, March 4, 1927.

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THE DETERMINATION OF RATES

It will be accepted as an axiom that, before it is possible to determine rates on any basis whatever, the cost to render service must be definitely known. Equally important is an accurate knowledge of the quantity of water pumped; displacement measurements are a delusion. Mature consideration is too frequently lacking in the building of a rate schedule which will create the necessary revenue and at the same time distribute it according to benefit. The cost of the plant is the first element involved and includes all expense of every character whatever up to the moment when the plant is ready for operation. Repairs, renewals, replacements, additions and betterments are the natural outcome of placing the plant in service. In private companies, the elements of franchises, good will and value as a going concern are attributes of value, inherent in a live plant. While such companies may or may not recognize those elements in their rate structure, they have a very tangible and recognized value where appraisals are being made for purchase. There should be sufficient revenue to give a fair return on the outstanding bonds or to retire debenture indebtedness; to meet the annual cost of operation; to provide a depreciation reserve for contingencies or for certain elements which may need replacement within their bonded life and to provide a working cash balance to reduce bank borrowings to a minimum. The creation of sinking funds in municipal practice is largely giving place to equal payment serial debentures and is eminently more satisfactory.

It is as essential in municipally owned waterworks that accurate information be available on which a rate schedule is to be based as it is in a privately owned company, which, in addition to giving adequate service, must show a profit for its shareholders. Without this information, a healthy plant condition cannot be maintained or equity be established as between consumers. With a high type of accounting, much statistical information of infinite value to the waterworks field would be made available, whereas much that is now available is not only misleading but inaccurate.

FIRE PROTECTION CHARGES

The vital question of fire protection charges rarely receives the analysis that it deserves. Since the investment for fire protection may represent 50 per cent of the total plant cost, depending on the

size of the municipality, it becomes the most important matter in the making of the rate schedule. There seems to be an undercurrent of opinion that a charge of about $35.00 per hydrant represents a fair return for fire protection benefit, while in fact there is no more justification for this than to assume that 10, 20 or any number of cents is the proper charge to be made per thousand gallons for water. The municipal council which will willingly assume for a community its fair and just proportion of this charge appears to be yet unborn. A fair fire protection charge has its proper place in the general tax, but rather than incur public criticism due to a rising mill rate, the line of least resistance is through the waterworks department, resulting in a water rate that is not equitable. Nor should the waterworks department be called upon to furnish "free" water to other civic departments or to civic institutions. Because certain public undertakings enjoy exemption from taxation conferred by the Legislature and over which municipal governments have no control, it does not follow that municipal councils should become generously philanthropic at the expense of the water department. The function of a water department is to distribute water, not to dispense charity.

The law does not prevent a municipally owned system from operating at a profit as a separate source of municipal revenue, if it is disposed to do so. Such operation may favor the owner who does not take water in proportion to the value of his property. On the other hand, if the plant is operated at a loss with a deficiency secured through the general tax rate, the water consumer is then favoured at the expense of the taxpayer.

The determination of the revenue for fire protection should not be secondary to that which is received from other sources, and each must be considered in relation to the other. The question of fire protection is the subject matter of another paper today and it will be assumed that the revenue to be derived from this source has been determined prior to the definite and final establishment of other rates.

READY-TO-SERVE EXPENDITURES

The service rendered by a water distribution organization is twofold. It must be prepared to serve a customer when service is asked which involves a definite capital outlay for pumping equipment, buildings, reservoirs, distribution mains and incidentals. This ready-to-serve expenditure is necessary regardless of the quantity used and

a reasonable charge for this service should be unquestioned. When a service connection is made there is an unwritten guarantee from the organization that water will be forthcoming whenever a demand is made in the system. When this occurs, an expense of an entirely different character is incurred. There is an outlay for labor, fuel, power and sundry other items. This is the cost of delivering the service which has been previously guaranteed and for which a charge may be made on the basis of the water actually supplied.

A minimum rate payable by each individual service connected to the distribution system regardless of whether or not any water is used has been shown by experience to be a necessity. Each service connection represents a certain portion of the total cost of the system and should naturally bear its share in the total cost of operation and maintenance. If half of the domestic consumers pay for water on the minimum rate basis, as is sometimes the case, it is apparent that unless the minimum rate is high enough, the revenue derivable from such sources is not commensurate with the cost of producing the service. In 1918, Allen Hazen, in "Water Rates for Waterworks" stated "Minimum rates are used by a great majority of waterworks systems. The service charge is being adopted in many rate schedules, but has not come into general use." Five years later the American Waterworks Association adopted a standard rate schedule recommending the service charge in preference to the minimum rate.

DIVERSITY IN RATE SCHEDULES

There is a wide diversity in the method of the collection of water rates in Canada. They naturally divide themselves into two classes; flat rates which involve any number of factors in their determination —assessment, frontage, floor or lot area, number of outlets, rentals, persons in the household—any method except sale by volume into which the second class falls. In the Canadian Municipal Index for 1926 there are 425 waterworks systems listed, of which 64 are private, 357 municipally owned and 4 controlled by the Dominion Government. Statistics of Canadian waterworks are very incomplete and those which follow were compiled from information contained in the Canadian Engineer of March 9, 1926. Figures given on 235 municipalities in tables 1 and 2 represent conditions in approximately 50 per cent of the systems in Canada.

From these tables it is apparent that the per capita consumption trend is upward with the size of the community; the per cent of serv-

ices metered, both industrial and domestic, increases with the population; 55 per cent of the communities have not any domestic meters installed; the domestic services of 70 per cent of the communities are

TABLE 1

Waterworks statistics of Canadian municipalities

POPULATION (CLASS)	NUMBER OF MUNICIPALITIES	AVERAGE POPULATION	PERSONS PER SERVICE	PER CAPITA CONSUMPTION	PER CENT OF SERVICES METERED		100 PER CENT METERED			
							Domestic		Industrial	
					Domestic	Industrial	Number	Per cent of total	Number	Per cent of total
				gallons						
0– 10,000	178	3,650	5.0	109	14.7	60.0	25	14	90	51
10,000– 25,000	36	15,100	4.9	124	24.9	78.1	4	11	23	64
25,000– 50,000	10	31,550	4.8	79	48.6	97.0	1	10	9	90
50,000–100,000	5	63,100	4.9	131	74.0	100.0	3	60	5	100
100,000 up	6	209,000	4.6	139	Accurate figures not available				6	100
	235									

TABLE 2

Data on number of metered services in Canadian municipalities

POPULATION (CLASS)	NUMBER OF MUNICIPALITIES	PER CENT OF SERVICES METERED											
		Unmetered		1–25		25–50		50–75		75–99		100	
		Domestic	Industrial	Domestic	Industrial	Domestic	Industrial	Domestic	Industrial	Domestic	Industrial	Domestic	Industrial
0– 10,000	178	105	41	18	12	6	9	11	21	13	5	25	90
10,000– 25,000	36	19	3	5	2	3	1	1	5	4	2	4	23
25,000– 50,000	10	3	0	1	0	1	0	1	1	3	0	1	9
50,000–100,000	5	0	0	1	0	0	0	1	0	0	0	3	5
	229	127	44	25	14	10	10	14	27	20	7	33	127

less than 50 per cent metered; the industrial services of 70 per cent of the communities are more than 50 per cent metered and 55 per cent of the communities are fully metered industrially. If any conclusion

may be drawn from averages, it might be deduced that the majority of those who are responsible for the policy of rate collections in those plants favor some system other than by meters.

In every waterworks system, engineering science, either elementary or advanced, plays some part. Is it possible, in determining rates to employ methods which verge on the scientific? How many equations involving assessment, frontage, house area, rental value, bathtubs, and family averages are necessary to determine X, where X equals the numbers of dollars which constitute a fair price to pay for service? There must be some happy combination of these factors, as 22 cities in table 2 collect all their domestic rates by one or other of these means, while the revenue of 4 only is derived on a metered basis. If their method of application is susceptible to refinement it should be equally applicable to industrial use. It is found, however, that 11 of these 22 cities completely meter all industrial services.

The complexity of a charge for water on an unmetered basis is illustrated in the meter ordinance passed by Chicago in 1925, an extract of which follows:

> The minimum amount to be charged for water to any unmetered premises ranges from \$3.50 for a building with a frontage of less than 15 feet to \$20.00 for a frontage not exceeding 87 feet. For each story in excess of one story, an additional charge of \$1.50 per annum shall be made. For each and every person in excess of twelve occupying any private residence, flat or apartment, an additional charge of 50 cents per annum is made. For each hose connection add \$2.00.

While the installation of meters to insure equitable rates is commendable, it must be proven in addition that they will be an economic benefit. As an investment a meter must save enough to pay for depreciation and interest on the investment. The outlay will be about \$20.00 per dwelling service. With a fifteen-year life there will be a depreciation of 6 per cent and on the basis of a 6 per cent return, the annual charge will be \$2.40. Increasing the meter life to 20 years reduces this by only 10 cents. Meter reading, billing and collecting will account for \$1.50 per service and the repairing and testing of meters not properly chargeable to the consumer may cost 60 cents. The installation of a meter thus imposes a total annual cost of \$4.50 per domestic service. In table 3 the average cost of water per 1,000 gallons is shown to be 38 cents, at which price it would require the meter to effect a saving of 12,000 gallons annually.

A pin hole leak in a washer, not badly worn, will account for 45,000 gallons per year. There is thus a fair possibility that a meter will justify its installation. To meter or not to meter is not pertinent to the subject matter of this paper, but if and when a policy of metering has been decided upon, the question of rates must have been under consideration at the same time.

Meter rates per 1,000 gallons vary from 5 cents in a small community in Ontario to $3.00 in a town in Saskatchewan. One community in Alberta quotes a price of 15 cents per barrel, while one in British Columbia uses the United States gallon.

As a result of a survey carried out by "Waterworks Engineering" to ascertain the merits of the cubic foot or gallon readings, the following conclusion may be drawn. Most of the meters already sold read

TABLE 3

Metered rates in Canadian municipalities according to population

POPULATION (CLASS)	NUMBER OF COMMUNITIES	AVERAGE MAXIMUM RATE PER 1000 GALLONS
		cents
Less than 10,000	113	42.7
10,000– 25,000	29	30.1
25,000– 50,000	9	28.0
50,000–100,000	6	23.4
More than 100,000	6	17.0
Total..................	163	
Weighted average.......		38.0

in cubic feet. This is not so much an indication of present day practice, as it is a survival of the system in vogue years ago. The tendency is favorable to the gallon and the movement is rapidly spreading. Some cities calibrate their meters one way and sell water by another scale of measurement. The average water consumer has some idea of the quantity represented by 10 gallons; talk to him in cubic feet and it is a language he does not understand.

The rates for 1916 were taken from "Water Works Statistics of Canada" published by The Commission of Conservation and do not represent 25 per cent of the systems in Canada. From figures compiled by "The American City" in 1925, the average highest meter rate per 1,000 gallons in the United States is 33.9 cents, ranging from a state average of 7.3 cents in Utah to 97.5 cents in Arizona. The

average best commercial rate is 14.1 cents ranging from 6 cents to 29.5 cents in the same two States. In Canada the average best commercial rate is given as 10.6 cents.

While the figures in table 4 represent conditions in only a small proportion of the plants in Canada, they are sufficient to indicate that rates have not kept pace with the increased price of commodities entering into the cost of delivering water. The average price of cast iron per ton for the period 1911–1916, f.o.b. New York, was $28.51, while it averaged $57.52 for the decade 1917–1926. The price in Canada would be $8.00 per ton additional, plus freight and sales tax.

TABLE 4

Comparison of meter rates in Canada

PROVINCE	NUMBER OF COMMUNITIES	MAXIMUM AVERAGE METER RATE PER 1000 GALLONS		PER CENT	
		1916	1926	Increase	Decrease
		cents	*cents*		
Prince Edward Island	2	30.0	30.0		
Nova Scotia	10	21.3	25.6	20	
New Brunswick	5	21.0	28.0	33	
Quebec	9	28.0	27.0		3
Ontario	45	24.0	27.3	14	
Manitoba	9	36.6	58.0	59	
Saskatchewan	10	57.0	74.5	31	
Alberta	8	55.6	37.4		33
British Columbia	5	30.0	25.0		16
Total	103				
Weighted average		31.1	34.1	9.7	

From "Contract Record" the figures in table 5 have been secured showing the trend of materials and labor since 1916.

While open to correction, it is doubtful if any waterworks operating in Canada has raised its rates 50 per cent since 1914, unless due to some special cause such as the construction of purification works.

UNIFORM MINIMUM RATES

A minimum amount is collected no matter how small the consumption may be. The minimum rate charge is in use in most communities and may be used either in connection with a uniform rate or any

one form of sliding or step charge. The service charge is absorbed in the minimum charge. The average yearly minimum charge paid in the United States is $10.10, varying from a state average of $4.80 in North Dakota to $24.00 in New Mexico. In Canada the average yearly minimum charge is $9.71.

GRADUATED MINIMUM RATE

In this form of rate, the minimum charge increases with the size of the meter. One of the most potent arguments for a minimum rate

TABLE 5

Price trends since 1916

YEAR	WEIGHTED AVERAGE OF 32 BUILDING MATERIALS	IRON AND ITS PRODUCTS 26 LINES	INDEX NUMBER OF RATES OF WAGES IN BUILDING TRADES
1913 Base	100.0	100.0	100.0
1916	103.8	151.8	102.4
1917	130.7	220.2	109.9
1918	150.5	227.3	125.9
1919	175.0	201.8	148.2
1920	214.9	244.4	180.9
1921	183.2	185.7	170.5
1922	162.2	151.8	162.5
1923	167.0	168.0	166.4
1924	159.1	161.1	169.7
1925	153.7	152.3	170.4
1926	149.1	145.2	172.1
Average since 1916...........	159.0	182.5	152.6

charge is in the fluctuating demand over the day in almost any plant In the City of Windsor municipal system the peak load is 32 per cent above the average, while in that operated by the Walkerville Water Company the average is exceeded by 46 per cent. Under extreme weather conditions these percentages will increase, which would be typical of the average plant. There is no information available to show that demand meters in waterworks operation have ever been advocated as is common practice in the electrical field. Rates are based and revenues are derivable from average and not from peak loads and, where every service constitutes a potential demand on the system, a minimum amount should be collected. As an instance of this, a

manufacturing plant connected to one of the above systems, but having a private supply heavily chlorinated for plant use, switched without notice last summer and made a million gallon demand in less than twenty-four hours. The peak loads in most systems are, in the main, caused by general use spread over all consumers and where 50 per cent additional plant capacity is necessary as a safe working margin, those for whom it is available should expect to pay a minimum amount.

SERVICE CHARGE

This is a fixed charge made in addition to a charge for water. It increases with the size of the meter or service connection.

SLIDING SCALE

This scale may be used with or without the minimum rate or service charge and includes all cases where a varying rate is charged according to the quantity of water used. This plan, with a minimum charge, is in most common use. The type of sliding scale generally used provides that the water used to a certain limit is charged at a certain rate and additional quantities are charged at lower rates, but the higher charge on the first quantity remains a part of the bill.

THE MILWAUKEE RATE SCHEDULE

A decision of some importance was recently rendered by the State Railroad Commission of Wisconsin. It denied the right of the large water consumers in Milwaukee to a sliding scale of rates. The rate within the city is $9\frac{1}{3}$ cents per 1000 gallons and a number of large consumers appealed against paying this amount. The application was opposed by the City of Milwaukee on the ground that any reduction made to large consumers must necessarily be made up by the large number of small consumers and this would be unfavorable to them. The decision which was favorable to the city established a precedent for waterworks practice, and received unfavorable editorial comment in "Waterworks Engineering." In reply, Mr. Bohmann, Superintendent of Waterworks, Milwaukee, showed that while the rate of $9\frac{1}{3}$ cents was constant, there actually was a sliding scale due to assessments for mains, service pipe and meter based on frontage. A minimum service charge of \$2.00 plus \$3.25 interest based on 30 feet frontage was imposed which applied to 92 per cent of all consumers, although the use of water ranged from 10,000 to 250,000

gallons. It is evident that, where only 10,000 gallons are used, the rate per 10,000 gallons would be considerably higher to absorb $5.25 than where the same amount is spread over 250,000 gallons. Mr. Bohmann contends that the advantage of a sliding scale is altogether on the side of a comparatively small number of consumers and, where a water utility is municipally owned, there should be no discrimination between consumers.

The difference in distribution cost furnishes a rational reason for the use of the sliding scale and it is rather difficult to justify a sliding scale on any other grounds. Sliding scales where extreme slides of 5 to 1 are still in evidence are legacies of earlier days in waterworks distribution. A sliding scale of 1.5 to 1.0 as applied to small domestic and large manufacturing use can be justified in any average community.

TABLE 6

Statistics on service charges in United States

SIZE OF METER	AMOUNT OF SERVICE CHARGE		
	Highest	Average	Lowest
inches	*dollars*	*dollars*	*dollars*
$\frac{5}{8}$	8.00	6.13	2.40
$\frac{3}{4}$	14.00	9.96	3.60
1	28.00	18.72	7.20
$1\frac{1}{2}$	72.00	42.40	14.40
2	96.00	62.10	24.00
3	232.00	138.00	33.60
4	336.00	205.40	43.20
6	632.00	401.40	72.00

THE AMERICAN AND NEW ENGLAND STANDARD SCHEDULES

In May, 1923, the American Waterworks Association adopted a standard form of rate schedule combining the service charge and sliding scale of three slides with a fourth or special rate for large manufacturers, if deemed desirable. The adopted form is almost identical with the standard of the New England Waterworks Association adopted in 1916. The three slides are for convenience classified as Domestic, Intermediate and Wholesale. While this has the endorsement of the Waterworks Association, it has not had as widespread adoption as the minimum rate.

The service charge for 19 companies or municipalities in the United States which have adopted the Standard Form of Meter Rates is given in table 6.

OTHER FORMS OF RATES

Several other forms have been used to a lesser extent. Many municipalities charge a uniform rate independently of the amount used. The jump scale provides that a certain quantity of water is charged for at a certain price; beyond that limit, while inside another limit, a lower price is named. By this method it is possible to secure a lower bill by drawing an additional quantity of water.

While the number of methods now in use for the collection of water rates appears to be legion, there must be some best method which is applicable to the majority of systems. That there is an utter lack of standardized practice is only too evident. In the electrical field as represented in Ontario by the Hydro Electric Power Commission, we find on all domestic bills a service charge and a minimum charge uniformly in use over the entire system. Some hydro electric officials are inclined to the belief that the present service charge, which is a modification of and an improvement on the former floor area charge, will give way to a straight uniform minimum charge. What is the value of a service charge when a minimum charge prevails at the same time? There cannot possibly be any standardization where rates are based on a "flat" or "complex" system. In a "simple" or "metered" system it should be possible. It is not desirable that all opinions on this subject should be in accord, but it does rest with waterworks officials and executives to install in their own community a rate system which is an equitable measure of the service rendered and which will admit of "value received" being endorsed on every bill.

THE FORT PIERCE FILTER PLANT[1]

By F. P. Larmon[2]

The problem at Fort Pierce was not only the design and construction of a filter plant but finding a suitable supply of water to filter, locating leaks and waste and introducing a new rate that would put the plant on a self-supporting basis.

The old supply was from deep wells which gave a water having a hardness of 330 parts per million and well tainted with salt and sulphur. The available sources of supply were two streams to the north and west which gave a fairly hard water high in color and more or less contaminated and a shallow lake or savannah south of the city, which was a soft but highly colored water. In fact most of the year it has the color of coffee. The savannah, while not ideal as to quantity, is near the city and little subject to contamination. It was decided to use the savannah water and later supplement it with water from one of the streams, if found necessary.

The plant is a standard type of rapid sand filter having two settling basins and three filter beds, each of one million gallons capacity per day and with a covered clear water reservoir of one-half million gallons capacity. The plant is of reinforced concrete including the building over the pumps and filters.

The water is pumped from the savannah by one of three pumps to an aerating device which consists of 12 inch pipes having $\frac{1}{2}$-inch holes drilled in the top so that the water is discharged vertically falling back on itself, flowing around the pipes in a thin sheet and dropping from the bottom into a collecting basin. This aeration drives off the marsh odors and some free CO_2 and raises the pH value from 6 to 6.8. At the outlet from the collecting basin the alum is added, 3 grains per gallon, the water is thoroughly mixed and 1 grain of lime per gallon is introduced. It has been found that, if the lime is added first, it fixes the color so that the alum will not remove it. A floc is formed very rapidly, but on account of the

[1] Presented before the Florida Section meeting, April 12, 1927.

[2] Designing Engineer, Fort Pierce, Fla.

absence of turbidity breaks up easily and settles slowly. The water passes through the settling basins to the filters which are of the standard type with hydraulically controlled valves, operated from tables, one for each filter. From there it goes to the clear well. The discharge into the clear well is arranged so that the water falls in a thin sheet thus giving it a second aerating. The resultant water is absolutely free from color, with a pH value of 7.0 and a hardness of under 70 parts per million.

The water is pumped to the city by one or more of three pumps giving a pressure in town of 70 pounds.

When the work was started here it was found that the office was billing for under 50 per cent of the water pumped. A general checking and cleaning of meters, repairing of leaks in mains and services and installing meters on services that had been lost track of, raised the percentage of "paid for" water to over 75 per cent and increased the revenue $700 in one month, with less pumpage than in the previous month.

Based on a pumpage of one million gallons per day the cost of water as delivered from the new plant will be 9.5 cents per thousand gallons. The cost of distribution, billing, collecting and supervision will be 9.4 cents. These costs include interest and sinking fund.

On the present rates of 10 cents for 1000 gallons the plant showed a deficit of $71 per day so that it was imperative that new rates be established. The new rates were based on the standard form adopted by the American Water Works Association. A service charge was made based on the size of meter installed and a charge for water as follows: First 20 thousand gallons 25 cents, next 40 thousand gallons 20 cents, next 40 thousand gallons 15 cents and all over 100 thousand gallons 10 cents. These rates will put the plant on a paying basis and will eliminate the necessity of carrying the water plant in the general fund.

DISINFECTION OF WATER MAINS[1]

By Charles H. Eastwood[2]

Unquestionably pollution, sometimes of the grossest nature, both avoidable and unavoidable, occurs in new mains, during the process of laying, and even the most uninformed of contractors and operators are sufficiently aware of this fact to carry out flushing of mains before putting them into service.

While this simple flushing is of material benefit, it does not begin to go far enough. Most of us are familiar with the story of the superintendent who, on investigating the inability to close a valve, discovered that its operation was impaired by the presence of an old shoe, presumably thrown into or left in the trench by a laborer, and which subsequently found its way into the main. The mere flushing of mains may serve to remove old shoes, mud and dirt of construction, but it will not do much towards removing bacterial contamination that undoubtedly has been introduced during the time the pipe has been exposed before and during laying.

METHODS OF DISINFECTION OF MAINS

A popular practice is to introduce a small amount of calcium hypochlorite (chloride of lime), roughly an ounce to each joint of pipe, into the pipe as it is laid. When the completed section has been connected up, the section is filled with water and this water is allowed to remain in the pipe overnight. Other than the relative instability of the calcium hypochlorite and the consequent inability to determine the actual presence of available chlorine in anything like constant amounts, there are no objections to this method.

With the almost universal practice of chlorination of water supplies and the availibility of liquid chlorine, water superintendents have more and more shown a desire to use liquid chlorine for sterilization of new mains. Unquestionably it presents the surest means

[1] Presented before the Florida Section meeting, April 12, 1927.

[2] Wallace and Tiernan Company, Newark, N. J.

of achieving the result. Provided some simple, cheap method of introducing it into the main is devised, the operation becomes one of simple routine and is associated with the laying of new mains almost as unconsciously as is the actual digging of the trench.

Almost every superintendent is capable of improvising a connection from the auxiliary tank valve, through a standard corporation cock, into the main. The only problem presenting itself is the extremely corrosive nature of the gas and the need for using connections that will not leak gas, either when first made or later when exposed to the influence of the corrosive effects of the chlorine.

Commercial forms of chlorine control equipment are entirely adapted to the purpose and where duplicate units of the relatively portable type are available at the water works, the problem no longer exists, as it is merely a question of transporting these to the desired point of application.

Where such units are not available a simple piece of equipment may be improvised from a standard connection into a main, such as is used on the smaller types of solution feed chlorine control equipment. This consists of an ordinary quarter inch gate valve fitted with a stuffing box and through which a small silver tube will slide. When desiring to disinfect a newly laid section of main the procedure resolves itself into several simple operations, as follows: The section of pipe should be flushed out thoroughly to remove all dirt, etc. Next tap the main and insert the connection with the silver tube withdrawn and the valve closed. Connect the silver tube through the medium of quarter inch rubber hose directly to the usual auxiliary tank valve on the standard chlorine cylinder. Care should be taken at this point to ensure all connections being gas tight. A little difficulty may be experienced in making the connection at the valve, but, if a valve is retained especially for this purpose, a permanent connection can be made by removing part of the union connection and litharging the joint.

Allow water to enter the section of the main to be disinfected at the minimum possible pressure. Turn on the gas, open the small gate valve and push the silver tube into the main.

It is well to bear in mind that, while we have the pressure of the gas in the cylinder to overcome the pressure in the main, any back pressure due to the pressure of water in the main is reflected back on the gas line and connections. It is advisable to keep this at a minimum.

CHLORINE DOSAGE

Ordinary practice entails a chlorine dosage of from 10 to 20 p.p.m., roughly 80 to 160 pounds of chlorine per million gallons of water.

This means that the water should be allowed to flow freely from the end of the section being sterilized until such time as it shows a heavy orange red color to the ortho-tolidine test; at this end of the pipe.

The silver tube can be withdrawn, the valve closed and the gas cut off. The closing of the valve and the cutting off of the gas should be done as nearly simultaneously as possible to avoid the building up of excessive gas pressure in the hose line or allowing water to get back to the cylinder valve. The valve is removed and the hole is plugged.

The heavily chlorinated water should be allowed to stand in the main for several hours and the main subsequently thoroughly flushed with fresh water to remove all excess chlorine.

Innumerable improvements in equipment and technique, ranging all the way from the simple addition of a standard diffusor and check valve to the use of standard solution feed equipment, present themselves to those familiar with chlorine gas control and chlorine gas control apparatus. Personally I should much prefer to amplify the method outlined through the use of a standard direct gas feed diffusor and chlorine check valve with the connections made through copper pipe and the usual union connection properly packed with gaskets. This means a larger investment, however, and would only be justified where there is considerable new main to be laid.

No accurate control of the chlorine dosage is possible or necessary with this method. The object is to put in chlorine and lots of it. As the cost of the gas is relatively small and the excess chlorine is subsequently removed by flushing the main, anything other than rough ortho-tolidine control is superfluous.

THE WHITE RIVER SURVEY[1]

By W. F. King[2]

The survey of White River was undertaken for the purpose of determining the degree and extent of pollution of the stream by domestic sewage and industrial waste from a number of cities located on the river and its tributaries. White River is an important stream, since it provides the only possible sewage outlet for an urban industrial population of more than one-half million, and at the same time furnishes a considerable part of the water supply for the same population. As the years go by, it is plain that not only will the population and industrial development of these cities increase, but that White River and its watershed must furnish more and more of the water supply for this population. In any effort to conserve and safeguard this water supply, the facts as determined in this survey should be helpful.

PLAN OF SURVEY

At a meeting attended by representatives of the State Conservation Department, the Sanitary District of Indianapolis, the Indianapolis Water Company, Indianapolis Health Department and the State Board of Health, a plan was agreed upon for conducting the survey. The Indianapolis Water Company collected samples for bacteriological and chemical examinations from a point above any sewer outlets at Muncie to the filter plant intake at Indianapolis. The Indianapolis Sanitary District collected samples from Washington Street, Indianapolis, to Martinsville, while the State Board of Health collected samples from Martinsville to Spencer. A total of twenty-eight sampling points was chosen extending along the river for a distance of approximately one hundred and fifty miles.

Samples were collected weekly, except during a few months of the winter of the years 1925 and 1926, when samples were collected once each two weeks. The actual field work was begun in July, 1925, and sampling was continued until October 1, 1926.

[1] Presented before the Indiana Section meeting, February 17, 1927.

[2] Secretary, State Board of Health, Indianapolis, Ind.

Coincident with the collection of samples the State Conservation Department, the Indianapolis Water Company and the Indianapolis Sanitary District began gauging White River and Fall Creek.

In the examination of samples the following determinations were included:

1. Alkalinity
2. Turbidity
3. Temperature
4. Dissolved oxygen
5. 5-day bio-chemical oxygen demand
6. Bacterial count—20°C.
7. Bacterial count—37°C.
8. B. coli content

In addition to the collection of samples and gauging, field surveys have been made and are being made to determine the sources of pollution along this part of the course of White River. Mr. Berg of the Conservation Department covered this part of the river five times at intervals of approximately three months, to determine the physical condition of the river and the extent of "larger biologic life" in the stream. Mr. Diggs of the State Conservation Department has made a survey of the larger industrial plants along the river to determine the amount and the physical characteristics of their industrial wastes. The State Board of Health is at present engaged in making a survey of the cities along the river for the purpose of determining the amount of domestic sewage which is being discharged into the stream. The city engineers and water works officials of the various cities along the stream have coöperated in the survey and have rendered valuable aid. The duty of coordinating the various parts of the survey into a completed report is being carried by the State Board of Health.

PRELIMINARY FINDINGS

While it is impossible to give a complete report of the survey at this time and to state any definite determinations or conclusions based upon the information obtained in the survey, some general observations may be made. The summer of 1925 after the survey was started was very dry and extremely low river stages occurred. The flow in the river at Anderson averaged 196 second feet during July, August and September 1925, while, during the same months in 1926, the flow was 1108 second feet. These two flows correspond

to 1470 and 8310 gallons per second at this point. The maximum average flow during any month of the entire survey occurred in September, 1926, when the average flow was 2587 second feet. The minimum average monthly flow occurred in August, 1925, with 41 second feet.

In the river above Indianapolis, the two points of maximum bacterial load were at Yorktown and Moss Island, i.e., below Muncie and Anderson. The data for the stretch below Indianapolis have not yet been compiled.

During the summer of 1925, the river at Moss Island was several times found to be devoid of dissolved oxygen. As would be expected, considering the low flow, the river was in its worst condition during July, August, September, 1925.

Mr. Berg, in his survey, reported the river in a foul condition at several points, i.e., a noticeably foul odor arose from it and no signs of fish life were noted.

Since the Indianapolis sewage disposal plant has been in operation the condition of the river below Indianapolis has improved to the extent that fish are now being caught at points where the river formerly would not support such life.

One type of industrial waste which caused trouble from 1903 until a few years ago has ceased to be a problem, i.e., the pollution of the river by oil well wastes. The petroleum wells produced oil and salt water, the salt water being drawn off and allowed to discharge into the nearest stream. This, with floating oil, caused a nuisance.

SOURCES OF WATER SUPPLY AND NATURE OF SEWAGE DISPOSAL

Of the towns and cities along the river the following use well supplies exclusively: Noblesville, Yorktown, Martinsville, Gosport and Spencer. Indianapolis, Anderson and Muncie draw their supplies from the river and also from wells.

At Muncie, Anderson, Noblesville, Martinsville and Spencer raw sewage, both domestic and industrial, is discharged into the river, Indianapolis being the only city to treat sewage.

Typhoid fever data from the various cities have not been compiled, but they will be and will furnish interesting facts.

Muncie, at present, is having a survey made to determine the proper method of collecting and treating its sewage, although they have not yet committed themselves to any actual construction work.

Anderson has been considering having a survey made, but, as far as is known, has not yet definitely decided to make the study.

In general, it may be stated that there is an excess of pollution in White River under any ordinary condition of stream flow below the city of Muncie, reaching its peak at or near Yorktown, with a similar condition below the city of Anderson, reaching its peak at or near Moss Island, with a slight excess of pollution shown below the city of Indianapolis, reaching its peak at or near Antrim. This excess pollution is particularly noticeable during the normal dry weather flow of the stream below Muncie and below Anderson. The excess pollution below the city of Indianapolis will undoubtedly disappear when the Indianapolis sewage treatment plant is in full operation and when all the sewage and industrial wastes of that city are subjected to treatment.

COMMENT ON A RECENT REPORT[1] ON "STANDARD METHODS OF WATER ANALYSIS"

By Emery J. Theriault[2]

In view of the widespread adoption of "Standard Methods for the Examination of Water and Sewage" and of the importance, in general, of accurate and workable methods of sanitary analysis, it has appeared advisable to the writer to present at this time the following comment on the "Report of Committee No. 1 on Standard Methods of Water Analysis" recently published in The Journal. The discussion will be limited to those sections of the report which refer to the determinations of (1) dissolved oxygen, (2) free chlorine, (3) biochemical oxygen demand, and (4) phenols in water supplies. On the whole, such criticism as may be offered will be based on experimental evidence which was not available to the various referees at the time (Buffalo Convention, June 11, 1926) when the report in question was submitted for publication.

I. THE DETERMINATION OF DISSOLVED OXYGEN

In the discussion which followed the original presentation of the permanganate modification of the Winkler method for dissolved oxygen, Rideal and Stewart (1901) stated that "Even in the presence of nitrites, ferrous iron and a large quantity of organic matter, this process gave results almost identical with the gasometric figures." The permanganate process recommended by Rideal and Stewart was first included in "Standard Methods" in 1917 and, in the sixth or 1925 edition of "Standard Methods" it is specified that this modification be used for the determination of the dissolved oxygen content of "polluted streams and other waters containing 0.1 part per million or more of nitrite nitrogen."

As regards the effectiveness of the Rideal-Stewart modification

[1] Report of Committee No. 1 on Standard Methods of Water Analysis, Jack J. Hinman, Chairman. Presented before the Buffalo Convention, June 11, 1926. Published in the January, 1927, issue of The Journal, pp. 112–126.

[2] Chemist, U. S. Public Health Service, Cincinnati, Ohio.

in counteracting the effect of nitrites, it is generally agreed that the method leaves little to be desired, at least if the full 20-minute period of action is allowed. However, as evidenced by data presented in Public Health Bulletin No. 151 (Theriault, 1925), it is necessary to conclude that as a corrective for "organic matter" the permanganate treatment has been overrated. Moreover, on the basis of the fairly conclusive evidence presented in the same Bulletin, it would appear that, in the presence of iron salts, the procedure outlined in "Standard Methods" should be perhaps modified to meet conditions which will presently be discussed.

The possibility of interference by iron salts was mentioned by Winkler (1888) and was further emphasized by Winkler (1915) who proposed the use of phosphoric acid for the final acidification when large amounts of iron were present. For small amounts of iron the use of sulfuric acid (instead of hydrochloric acid) was apparently considered a sufficient precaution. Winkler's results were fully confirmed by Bruhns (1916). Hydrochloric acid was found to aggravate the difficulty. The results presented by Bruhns indicate that iron up to 100 parts per million or over does not offer any serious difficulty.

In this country, Swanson and Hulett (1915) first called attention to the fact that "in attempting to determine the dissolved oxygen in mine waters, the presence of both ferrous and ferric iron interferes with the usual procedure." Buswell and Gallaher (1923) have also reported on the interference of iron salts "in attempting to determine the dissolved oxygen in a stream polluted with waste liquor from a galvanizing plant as well as domestic sewage." Without knowledge of the earlier work of Winkler (1915) and of the fairly extensive report by Bruhns (1916), these experimenters conclude that "Since the Winkler method apparently could not be modified for use in the presence of iron, the next step was to investigate some other method. Of those mentioned (above) the Levy-Mohr method seemed to be the one most likely to work in the presence of iron, since an iron solution is added during the procedure and therefore any iron already in the water should have no effect."

In passing, it should be noted that the tests cited by Buswell and Gallaher in support of their conclusions were performed on solutions which contained only potassium iodide, ferric salts and hydrochloric acid, so that the conditions of their experiments conformed more nearly to those recommended for the determination of iodides by ferric

chloride than to those prescribed in the Rideal-Stewart modification of the Winkler method. Moreover, the titrations were delayed for 12 hours.

A repetition by the writer (Theriault, 1925) of the experiments of Buswell and Gallaher led to certain conclusions which may briefly be summarized as follows:

a. Low results will, of course, be obtained when the unmodified or original Winkler method is applied to samples containing ferrous salts. The error is in the neighborhood of 0.14 part per million of dissolved oxygen for each part per million of ferrous iron. With most waters, therefore, the error is negligibly small.

b. In the absence of other interfering substances, accurate results may be obtained when the Rideal-Stewart modification of the Winkler method outlined in "Standard Methods" (1925, p. 60) is applied to samples containing relatively large quantities of either ferrous or ferric salts, provided that the decolorization of the samples by oxalates (following the addition of permanganate) is accomplished in the dark and that the titrations are performed immediately after the final acidification.

c. The necessity for conducting the decolorization in the dark arises from the fact that, under the experimental conditions, the reduction of ferric salts is greatly accelerated by sunlight. When this precaution is neglected the results will appear too low. On the other hand, should the decolorization be imperfect, the results will appear unduly high.

d. "Under the particular conditions imposed by the Rideal-Stewart modification, the decolorization of the permanganate by oxalates is retarded to a surprising extent when iron salts are present. Fluorides (2 cc. of a 40 per cent solution of $KF \cdot 2H_2O$ in 300 cc. of sample) may be used to good advantage to diminish the period of decolorization and to eliminate interference due to iron salts when the delay before titration does not exceed one hour."

e. "Phosphoric acid ('4 cc. of 85 per cent H_3PO in 300 cc. of sample') should be substituted for sulfuric acid (for the final acidification) when the delay before titration is protracted."

Primarily, therefore, the use of potassium fluoride has been suggested by the writer as a means of inducing a more rapid decolorization of the samples. Apart from this beneficial effect, potassium fluoride in the amounts stated is also fairly effective in repressing the deleterious effect of iron salts. Owing to its limited solubility, the

use of the less expensive sodium fluoride is restricted to samples which contain relatively small amounts of iron (cf. Public Health Bulletin No. 151, pp. 35 and 36). In laboratories where the titrations must of necessity be delayed, the modified Winkler procedure should be used (Winkler, 1915; Bruhns, 1916). Essentially, this modification consists in the substitution of phosphoric acid for sulfuric acid in the final acidification.

It is difficult to reconcile the foregoing statement of the recommendations actually made in Public Health Bulletin No. 151 with the following abstract given on page 120 of the January issue of The Journal:

> In Public Health Bulletin No. 151 ("The Determination of Dissolved Oxygen by the Winkler Method") it is suggested by the author, E. J. Theriault, that the oxidizing effect of ferric chloride could be inhibited by the addition of sodium fluoride, and he proposed this as a modification of the Winkler method for liquors containing iron. Unfortunately, he did not use in his experiments as large amounts of iron as are sometimes found in actual field tests, and until further work is done along this line, the advisability of including his suggested modification is still somewhat in doubt.

It is earnestly recommended that, when further work along these lines is undertaken by the Committee, due consideration be given to the combined use of potassium fluoride and phosphoric acid, following the procedure set forth in detail in Public Health Bulletin No. 151. As indicated by the data presented in that Bulletin, the procedure actually recommended is apparently capable of giving exceedingly accurate results in the presence of 120 parts per million of iron even when the titrations are delayed for 8 days. At the time when these experiments were made, it was believed that this degree of flexibility would satisfy the conditions usually encountered in sanitary chemical work. The method is no doubt capable of giving accurate results even when the figure of 120 parts per million of iron is greatly exceeded. Likewise, the figure of 8 days refers to the duration of a particular experiment and not to an upper limit of applicability. As a practical matter, it is to be borne in mind that the dissolved oxygen in a waste may be of negligible importance when its ferrous iron content greatly exceeds 100 parts per million.

II. THE DETERMINATION OF FREE CHLORINE

In connection with the studies reported by Buswell and Boruff on the preparation of the orthotolidine reagent for use in the deter-

mination of free chlorine, attention is directed to a brief article by Roake (1925). Roake found it difficult to prepare an orthotolidine solution in accordance with the directions given in "Standard Methods" (Sixth Edition, p. 44). The orthotolidine does not dissolve completely, at least in a reasonable time, and, on filtering off the undissolved part, a weaker solution is obtained than called for. He gives the following directions for preparing the reagent:

> To 1 gram of *o*-tolidine add the calculated amount of hydrochloric acid ("about 236 cc."), stir well, dilute to about 500 cc. and filter. The residue left on the filter will be found to be soluble in distilled water. Make up to 1 liter.

The following procedure avoids the filtration recommended by Roake and has been found very satisfactory both in this and in several other laboratories·

a. Transfer one gram of orthotolidine to a 6-inch mortar, and add 5 cc. of 1:5 hydrochloric acid (previously prepared by adding 100 cc. of concentrated hydrochloric acid, specific gravity 1.18–1.19, to 400 cc. of distilled water).

b. Grind to a thin paste and add 150 to 200 cc. of distilled water. The orthotolidine goes into solution immediately.

c. Transfer to a 1000 cc. graduate and make up to 505 cc. with distilled water.

d. Make up to the 1000 cc. mark by adding the balance (495 cc.) of the 1:5 hydrochloric acid.

The reader is referred to Public Health Reports, March 11, 1927, for further details.

III. THE DETERMINATION OF BIOCHEMICAL OXYGEN DEMAND

With reference to the so-called "second stage" of deoxygenation, the Committee on Standard Methods presents the following comment:

> Results have shown that the demand for oxygen is far from being satisfied in twenty days at 20°C., but that absorption takes place in two stages, the first extending over ten days at 20°C., the second over a period of months. In explanation of the secondary phase, Theriault believes that it is the stage of nitrification, while the first stage is the stage of carbon oxidation; Greenfield and Elder believe the secondary phase is primarily the demand of dead organisms. The latter investigators claim the second stage was not obtained with sewage, but only with river water, while Theriault claims to have had similar results both with sewage and river water. This divergence of opinion must be reconciled by further work.

In this connection attention is invited to a more recent publication by Greenfield, Elder and McMurray (1926), in which the conclusion is reached that the presence or absence of either living or dead plankton "does not explain the second period of acceleration in deoxygenation curves. . . . ."

It was suggested by Theriault that these two-stage curves were best explained by the work of Adeney in which he showed that in the oxidation of organic matter the first stage was one of carbonaceous oxidation, which was followed by a stage of nitrification of nitrogenous compounds. . . . . The results seem to be a confirmation of Adeney's theory of two-stage oxidation.

In their experiments, however, both Greenfield and Elder (1925) and, more recently, Greenfield, Elder and McMurray (1926), appear to have assumed that sewage is free from plankton. A systematic error is thereby introduced in their work which seriously vitiates their conclusions. Unpublished data obtained in the Stream Pollution Laboratory of the United States Public Health Service would indicate that the plankton are undoubtedly active in promoting deoxygenation.

IV. THE DETERMINATION OF PHENOLS IN WATER SUPPLIES

Attention is invited to the comprehensive review of tests for phenols which has recently been prepared at the Hygienic Laboratory of the United States Public Health Service (Gibbs, 1926).

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DISCUSSION

A. M. BUSWELL:[3] Captain Theriault states that the criticism of the Winkler Method by Buswell and Gallaher is based on experiments which "conformed more nearly to those recommended for the determination of iodides by ferric chloride than to those prescribed in the Rideal-Stewart modification of the Winkler Method. Moreover, the titrations were delayed for twelve hours." We wish to call attention to the fact that the criticism of the Winkler Method was based on field experience with the method carried out with the Rideal-Stewart modification as specified by Standard Methods. In this field work titration results showed considerable quantities of dissolved oxygen, although the conditions were such that the sample contained no dissolved oxygen. The experiments to which Theriault refers, as the article clearly indicates, were carried out to determine whether under the most favorable conditions the reaction with iron was sufficiently complete to warrant making a correction of the figure obtained by the Winkler Method (Rideal-Stewart Modification), if the iron content were known. Since this was not found practicable under conditions which favored the reaction between iron and salts, further attempt to determine a correction factor was abandoned. The intent of the article is stated by Buswell and Gallaher as follows:

> Whether or not the criticisms of this method are false cannot be judged without a much fuller investigation. The data, however, show that the Levy method can be used in the presence of iron and will give far more accuracy than the Winkler Method, Rideal and Stewart modification.

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[3] Chief, State Water Survey Division, Urbana, Ill.

Concerning the determination of biochemical oxygen demand Mr. Elder has furnished the following statement:

Since Greenfield, Elder, and McMurray were working with quite high concentrations of plankton in the river water[4] dilutions, relatively, therefore, the number of plankton in sewage was negligible. It was never assumed by them that sewage was free from plankton.

Attention is called to the work of Greenfield, Elder and McMurray on the effect of salt concentration on[4] biochemical oxygen demand. By adding certain inorganic salts to the double distilled dilution water, two-stage biochemical oxygen demand curves were obtained. Nitrification was also noted under these conditions.

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[4] See Theriault bibliography, loc. cit.

ELECTROLYTIC CHLORINATION

C. T. Henderson:[1] Harry N. Jenks' excellent paper entitled "Electrolytic Chlorination at Sacramento Filtration Plant"[2] is particularly interesting to the writer on account of his experience over a number of years in the design, construction and operation of electrolytic plants of the same general character, but of much greater magnitude.

Mr. Jenks is certainly to be congratulated on the thoroughness with which he has covered the present situation. The City of Sacramento is certainly fortunate in having a man of Mr. Lundelius' qualifications available, for he is able not only to design, but to operate electrolytic cells. The availability of Mr. Lundelius has made possible the construction of electrolytic cells at Sacramento without engineering or license fees, but for future installations it would seem only proper to increase the capital charge and include engineering fees for design, and license fees for use of patents covering the type of cells installed. The cells described by Mr. Jenks seem to infringe several patents and yet there is no item of royalty or license included in the itemized statement of plant costs.

The cost figures given by Mr. Jenks show no operating labor costs, presumably on the theory that no extra labor is involved over that required to run the filter plant. This seems an obvious fallacy for by following this line of reasoning to its logical conclusion, nothing in the plant would cost anything, since, after all, each individual operation carried on may be said to be carried on in spare time. Certainly, however, there is extra labor involved, for example, in the handling of the 191 tons of salt required by the plant in the course of the year. This handling at 50 cents per ton would amount to 0.11 cent per pound of chlorine produced. It would, also, seem only fair to charge say $150 per month for supervision, laboratory checks, etc., which at 100 per cent scale of operations will amount to 2.16 cents per pound of chlorine produced.

[1] Vice-President, Great Western Electro-Chemical Company, San Francisco, Cal.

[2] See Journal, May, 1927, page 514.

Mr. Jenks figures no repairs on brine equipment. Those familiar with the corrosive effect of saturated brine will agree that no doubt repairs will be required on the brine equipment at frequent intervals.

Again, Mr. Jenks' figures on depreciation for electrical machinery seem too low. Does the reader know of a half dozen pieces of electrical equipment twenty years old which are in regular service today? Yet Mr. Jenks assumes in his cost estimates a twenty-five-year life for his electrical equipment; a fifteen-year life seems more nearly correct to the writer. Also, accidents are bound to occur to electrical machinery, yet no electrical repair charges are included in the cost figures.

In calculating cell maintenance Mr. Jenks apparently makes the assumption that the labor cost of completely rebuilding the cell will be the same as the original labor cost of construction. The writer's experience shows that repair labor will be at least 50 per cent greater than the original labor required to construct.

Again, figures for the life of the various parts of the electrolytic cells do not agree with the writer's experience and observations. The principal differences are in the life of anodes and effluent pans. The writer's experience in this connection would indicate that anode life will be approximately nine months and the life of effluent pans two years, as against two and five years respectively, taken in Mr. Jenks' estimate. Also, diaphragm renewals will cost, according to the writer's experience with cells of similar size $4.77 each.

Correcting for the above differences, we have the revisions of tables 2 and 3.

Tables 4 and 5 have likewise been revised in accordance with revised tables 2 and 3, and have been extended to show the effect of operating at 80 and 90 per cent of *full* capacity, since variations in chlorine dosage will preclude possibility of full operation at all times.

In making up table 5, the price of liquid chlorine has been taken as 8.25 cents per pound, since liquid chlorine in one ton containers is available at Sacramento, California, at the price of $8\frac{1}{4}$ cents per pound.

An analysis of the foregoing figures shows that even on the basis of 100 per cent operation, the electrolytic plant produces chlorine at a higher cost than purchased chlorine, while at lower productions the cost of "home made" chlorine materially exceeds that of purchased chlorine.

It is indeed regrettable that after two and one-half years actual

REVISED TABLE 2

Schedule of chlorine plant depreciation

	PROBABLE USEFUL LIFE	STRAIGHT LINE ANNUAL DEPRECIATION
	years	*per cent*
1. Brine equipment	10	10
2. Electrical equipment	15	6.66
3. Chlorine lines	5	20
4. Electrolytic cells		
a. Cell body	5	20
b. Cell cover	1	100
c. Anode assembly	$\frac{3}{4}$	133
d. Cathode plate	1	100
e. Effluent pan	2	50
f. Diaphragm	$\frac{1}{4}$	400
g. Electrical connections	2	50

REVISED TABLE 3

Annual fixed charges, electrolytic chlorine plant Sacramento, California

	COST	ANNUAL STRAIGAT LINE DEPRECIATION	
		Per cent	Total
1. Brine equipment	$1,500	10	$150.00
2. Electrical equipment	4,800	6.66	319.68
3. Chlorine lines	275	20	55.00
4. Electrolytic cells	1,596	Various	1,292.33
	$8,171	11.7	$1,816.91
Assume interest charges at 5 per cent (0.05 × $8,171)			$408.55
Total annual fixed charges			$2,225.46
Capital cost of chlorine on basis of *full* plant production, per pound of chlorine			$0.0267
Capital cost of chlorine on basis of 90 per cent plant production, per pound of chlorine			0.0297
Capital cost of chlorine on basis of 80 per cent plant production, per pound of chlorine			0.0334

operation of the Sacramento plant there are no definite *actual* cost figures available and that the merits of the installation must be considered on the basis of *estimated* costs which are always contro-

versial. The experienced operator of chlorine plants who has been compelled to show profits to a doubting board of directors is apt to be conservative and estimate higher than the man whose experience has been limited and who does not realize the high maintenance costs, after three or four years, which are inevitable in a chlorine plant. It takes time for the corrosion to start making trouble with

REVISED TABLE 4

Summary of actual cost of manufacture of electrolytic chlorine at Sacramento Filtration Plant

	PER POUND OF CHLORINE		
	80 per cent	90 per cent	100 per cent
	cents	*cents*	*cents*
Capital charges	3.34	2.97	2.67
Operating cost:			
Electric current	2.30 } 4.02	4.02	4.02
Salt	1.72 }		
Salt handling	0.11	0.11	0.11
Supervision @ $150.00 per month	2.70	2.40	2.16
	10.17	9.50	8.96

REVISED TABLE 5

Analysis of cost of chlorination with liquid chlorine in comparison with that of electrolytic chlorination

	COST PER POUND OF CHLORINE		
	80 per cent	90 per cent	100 per cent
	cents	*cents*	*cents*
Liquid chlorine apparatus annual fixed charges	0.79	0.70	0.63
Liquid chlorine, operating cost	8.25	8.25	8.25
Total	9.04	8.95	8.88

certain major parts of the equipment, but after the trouble starts it is seemingly unending.

The writer's conclusions in the matter would be that in no case would it pay a municipality to consider the production of their own chlorine unless a man of Mr. Lundelius' experience and capabilities is available, and that, even with such a man available, the cost of

"home made" chlorine will at least equal, and if *proper labor charges are actually applied to the production of chlorine,* exceed the cost of purchased chlorine.

Harry N. Jenks:[3] In discussing such a subject as the one presented in the writer's paper on electrolytic chlorination, it appears only natural that there should be considerable room for differences of opinion on the very points emphasized by Mr. C. T. Henderson. In the interests of a clear understanding of the situation, however, one should bear in mind that the matter is viewed by Mr. Henderson largely from the manufacturer's standpoint, while the purpose of the writer's paper was primarily to call attention to the fact that electrolytic chlorination may be a profitable undertaking as an adjunct to water treatment, as proved by ample experience at Sacramento.

The writer is not disposed to take issue with Mr. Henderson on questions concerning the manufacture of chlorine as such, for it will be recognized that his contentions relating to labor and certain depreciation charges would be entirely pertinent in the case of a liquid chlorine plant. In the interests of strict accounting, it may be admitted that the item of supervision should be included as a separate charge. It will be apparent to water works operators, however, that the operation of an electrolytic chlorine plant is in no essential different from that of a liquid chlorine installation, and constitutes one of the regular duties of the filter operators. The writer believes that the operating cost for the two methods in general would be about the same, and in the comparison between them on the basis of cost, no extra charge should be made against either.

In any event, sufficient allowance in cost figures has been made to cover handling of salt, since salt may be obtained f.o.b. the filtration plant for \$7.10 per ton, whereas \$7.50 per ton has been allowed. Moreover, the writer cannot agree that \$150 per month is a correct figure to use for laboratory tests and supervision of the plant. As every water works operator knows, in medium and large sized plants such checks are quite incidental to the volume of routine analyses performed, and at the most would not amount to half Mr. Henderson's proposed charge. Again, the writer would point out that this same charge should be made against any standard chlorine equipment when cost comparisons are to be made.

[3] Sanitary Engineer; Associate Professor of Sanitary Engineering, Iowa State College, Ames, Iowa.

Mr. Henderson criticizes the lack of maintenance charges against the brine equipment. As a matter of fact such a charge has actually been allowed for under the heading of depreciation. During two and one-half years' operation, no repairs of any kind have had to be made amounting to more than \$5 or \$10. A similar observation applies to the electrical equipment. Especially with duplicate motor-generator apparatus, there is no good reason to suppose that it should not give satisfactory service for twenty-five years. Even a General Electric representative might admit as much relative to Westinghouse equipment!

As to the labor cost of rebuilding a cell, it is anticipated that the expense, rather than being 50 per cent greater than for the original equipment, may in reality be somewhat less, because of the patterns and plans already at hand to serve as a guide.

In reference to Mr. Henderson's experience and observations on the life of anodes and effluent pans, there can be little doubt but that with a less rugged and straightforward design for these parts, a life of only nine months and two years, respectively, may be expected. With the cells as designed at Sacramento, the writer's experience has been different from Mr. Henderson's, although not necessarily untrustworthy on that account. Mention of the design of the cells reminds the writer to state that, because they embody several novel and improved features, they are themselves patentable and presumably do not infringe on similar patent rights. However, the design of the Sacramento cells is not patented and may be freely followed by those who wish to make their own equipment.

Regarding Mr. Henderson's statement that "it is indeed regrettable that after two and one-half years actual operation of the Sacramento plant, there are not definite *actual* cost figures available," the writer is tempted to ask what costs other than actual costs can actual operation disclose?

Again, in answer to Mr. Henderson's last paragraph, the writer, with all due respect to Mr. Lundelius' experience and ability, may be pardoned for expressing his modest belief that in every water filtration plant of note in this country there is enough executive and technical skill available for the purpose of designing and operating a small electrolytic chlorine plant along with the multitude of more intricate problems daily met and solved by water works superintendents.

Finally, and what is more to the point than argumentation, the writer has learned from engineering friends in California that the operation of the Sacramento electrolytic chlorine plant has already led to a substantial lowering of the price of liquid chlorine on the Pacific Coast. Accordingly, in closing, the writer wishes to correct one of the conclusions of his paper, to the effect that "the advantage of electrolytic chlorination is dependent primarily on there being a substantial margin between the market price of liquid chlorine and the actual cost of production locally at the treatment plant, a condition that prevails in the West." This should now read, "a condition that *used* to prevail in the West," if the writer's information on this point is correct. Hence it appears that Mr. Henderson in the end has proved at least this part of his thesis, that "in no case would it pay a municipality to consider the production of their own chlorine," provided it is remembered that electrolytic chlorination costs have not gone up, but that, instead, liquid chlorine prices have come down.

John Ericson

Died April 16, 1927

In the sudden death of John Ericson, City Engineer of Chicago, the water works profession has lost an eminent engineer and this society an honored and respected member. News of his passing was a great shock to all. His death was particularly untimely in view of the active part he was taking in preparing for the 47th Annual Convention of the American Water Works Association. It was under his direction, as chairman of the Chicago local committee, that most elaborate plans had been made for the greatest water works meeting in the history of the association. He was scheduled to read at the "Chicago Night" session on Tuesday, June 7, a paper entitled "A Program for Improving the Water Service in Chicago," and considering the thoroughness with which he prepared material of this kind this paper would probably have been a classic contribution toward the solution of Chicago's water supply problems.

John Ericson was born October 21, 1857, in Stockholm, Sweden. He was graduated from the Royal Polytechnic Institute in that city in 1880, receiving the degree of Civil Engineer. After being employed on bridge construction work in Sweden for a year he came to the United States. He began his engineering career in America as a rodman for the Pennsylvania Railroad and was promoted to a resident engineer by that company in 1882. In 1883 he was engaged in survey work on the Illinois-Michigan Canal.

Mr. Ericson began his career in the employ of the City of Chicago in 1884 as a draftsman, which position he held for two years. In 1886 he accepted a position as assistant engineer with the city of Seattle, in connection with the design of the new water works for that city. In 1890 he returned to Chicago and was employed for two years as an assistant engineer with the Sanitary District. He re-entered the employ of the City of Chicago in 1892 as an assistant

engineer on water tunnel construction work, where he rendered exceptional service. In recognition of his work Mr. Ericson was made first assistant city engineer in 1893. On July 6, 1897, he was appointed to the position of City Engineer. He served continuously in this office until his death, except for a four-year period, 1919 to 1923, when he was employed as consulting engineer to the Department of Public Works.

When Mr. Ericson first entered the employ of the City in 1884 the Chicago water works system consisted of one crib, 11 miles of tunnels, 2 pumping stations having a capacity of 134 M.G.D. and about 533 miles of cast iron pipe in the distribution system. At the time of his death this system had increased to 6 intake cribs, 70 miles of tunnels, 11 pumping stations and 3400 miles of cast iron mains.

During the 43 years of his service Chicago had a phenomenal growth as a city. The engineering problems in developing the water works system to meet the demands for an increased supply required engineering skill and foresight of a high order. Through the period of multiple annexations of suburbs, each with its own water supply system, there was serious need for the formulation of a sound technical program for the building of a great water works system from these many units. It was indeed fortunate for Chicago that it had at the head of its Engineering Bureau a man of Mr. Ericson's high qualifications. He may truly be called the builder of the present water works system in Chicago.

As City Engineer Mr. Ericson had charge of the design and construction of many bridges for the City of Chicago during the last three decades. He designed a type of bascule bridge in 1898 that enabled the city to build its bridges without paying royalties. In 1909 he submitted an excellent report on investigations of underground conditions affecting the future subway construction. From 1911 to 1914 he served on the Harbor and Subway Commission. Projects under construction now which were designed and begun under his direction are the Western avenue pumping station and the new Chicago avenue tunnel.

For years Mr. Ericson advocated filtration of Chicago's water supply and in 1925 submitted to Colonel A. A. Sprague, Commissioner of Public Works, an official report on "The Quality Problem in Relation to Chicago's Water Supply," in which specific recommendations were made for the construction of an experimental filter plant to be operated over a period of years to enable the collection

of fundamental data on which to base the design of filtration plants for the city. This experimental plant is now under construction.

Mr. Ericson was an active member in the American Water Works Association and contributed many valuable technical papers to its programs. Last year in Buffalo his paper on "Universal Metering In Chicago" was enthusiastically received, being typical of the engineer he was in its thoroughness. He was a member of the American Society of Civil Engineers, the Western Society of Engineers, the American Society of Mechanical Engineers, the American Association of Engineers, the Swedish Engineers Club and the Swedish Club. He was a Mason, Shriner and Knights Templar.

In 1912 Mr. Ericson was awarded the Octave Chanute medal of the Western Society of Engineers for a paper reporting the results of extensive experiments to determine the flow of water in the northwest land tunnel. Mr. Ericson was decorated with the Royal Order of Vassa by the King of Sweden in 1913.

Mr. Ericson is survived by his wife, Esther Malmgren Ericson, and a daughter, Mrs. Ralph Haven Quinlan of California.

Arthur E. Gorman.

Fred C. Smith

Died November 16, 1926

Fred C. Smith, superintendent of the water department, Euclid, Ohio, died suddenly on November 16, 1926.

Mr. Smith is survived by his wife and five sons. The family has lived in this vicinity about 11 years, moving from Ashtabula, where Mr. and Mrs. Smith were married. He was born in Rootstown, Portage county, 50 years ago, July 3 last.

Mr. Smith was elected a member of the board of public affairs of Euclid village in November, 1925. He resigned soon after taking office in January, however, and was appointed water superintendent by the other two members of the board.

Mr. Smith followed the plumber's trade for 24 years. He had been in business for himself at his home about a year before taking charge of the Euclid department. Previous to that he had been employed by the Wehrle Hardware Company of East Cleveland. Mr. Smith is credited with having invented the modern drinking fountain for school and public building use.

Oscar E. Bulkeley

Died January 4, 1927

Oscar E. Bulkeley was born April 2, 1885, at Oneida, Ill. His parents were John A. and Emma H. Bulkeley. With his parents, at the age of five years, he moved to Grand Junction, Col. There his mother died when he was 12. Three years later he and his father went to Riverside, Cal., where his high school education was completed.

Oscar Bulkeley was graduated, with first honors, from Knox College, at Galesburg, Ill. with the class of 1905 as bachelor of science. He was 20 years old at this time, having taken but three years to complete his college course. In 1906 he went to Butte, Mont., wishing to gain practical experience in mining. He entered the mines of the Anaconda Copper company, taking up a pick and shovel and going down into the copper workings. His ability was soon recognized and before leaving he had attained the position of general purchasing agent.

In January, 1910, he entered the University of Illinois and was graduated there, in civil engineering, with the class of 1912. Immediately after graduating from the university he took the position of assistant superintendent of the water department at Rockford, Ill. He was married about this time to Edna Best of Los Angeles, Cal., the culmination of a school days' romance.

After serving at Rockford three years Mr. Bulkeley came to the water works in Jackson. Early in 1918 he entered the service of the government in the erection of the large powder plant being built near Nashville, Tenn. In the fall he was placed in charge of the entire water works system, a plant of great magnitude.

In January, 1920, he came to Lansing and became superintendent for the board of water and electric light commissioners which position he held until his death.

He was ever ardent in behalf of the best interests of his city and always gave aid toward building up Lansing. He was untiring in his efforts to work out the new street lighting system, the removal of overhead wires in the downtown section, and in the development of an adequate water supply, all with a broad vision of the future needs of the city. The city mourns the loss of a faithful servant and an ideal citizen in the full sense of the word.

He and Mrs. Bulkeley joined the Plymouth Congregational church soon after coming to Lansing. He always took an active part in its work.

Mr. Bulkeley was a member of Phi Gamma Delta and Tau Beta Pi societies. He was also a member of the American Society of Civil Engineers, the American Water Works Association, the Rotary club and the Masonic order.

He is survived by the widow, Edna Best Bulkeley; two children, Mary Louise and William Warren; and a brother, Claude A., of Wilmington, Del.

RESOLUTION ON DEATH OF MERRITT H. SMITH

Whereas through the death of Colonel Merritt Haviland Smith on December 9, 1926, the New York Section of the American Water Works Association has lost one of its most prominent and popular members, who by his personality endeared himself to all;

Therefore Be It Resolved that the members of the Section hereby recognize Colonel Smith's ability in water works matters, his efficient work for the City of New York as engineer and for the last thirteen years as Chief Engineer of Water Supply, his devotion to his country as evidenced by his service in the New York State Militia and the United States Army in the Spanish-American War, on the Mexican Border and in the World War, and the great loss his death entails to his many friends both within and without the American Water Works Association, and be it

Further Resolved that this resolution be spread upon the minutes of the New York Section, sent to the Publication Committee to be printed in the Journal, and a copy be sent to Mrs. Merritt H. Smith.

ABSTRACTS OF WATER WORKS LITERATURE

Frank Hannan

Key: American Journal of Public Health, **12**: 1, 16, January, 1922. The figure 12 refers to the volume, 1 to the number of the issue, and 16 to the page of the Journal.

Why Boiler Tubes Burnt Out. G. C. Reinhard. Power, **63**: 51–3, 1926. From Chem. Abst., **20**: 1585, May 20, 1926. Corrosion of tubes in oil-fired boiler appeared to be related to formation of ferrous and ferric sulfates on tubes. Fused sulfates acted as flux for the iron, weakening tube enough to cause blistering and blowouts. The cleaner the tubes were, the more rapidly did corrosion occur.—*R. E. Thompson.*

Peculiar Examples of Corrosion of Boiler Parts. Robert Stumper. Feuerungstechnik, **14**: 97–8, 1926. From Chem. Abst., **20**: 1585, May 20, 1926. Piece of open-hearth steel in contact with chromium-nickel steel lost about twice as much by corrosion as an isolated piece in same water. Anodic corrosion of bronze containing 2.4 per cent zinc occurred in boiler water having 0.5 gram sodium carbonate per liter.—*R. E. Thompson.*

Autogenous and Electrically Welded Boilers and Tanks (Holders). E. Höhn. Z. Ver. deut. Ing., **70**: 117–22, 1926. From Chem. Abst., **20**: 1585, May 20, 1926. Comprehensive illustrated report on tests conducted for an association of steam boiler owners in Switzerland, covering welding by water gas, oxy-acetylene, and electric arc; comparisons with riveted joints and seams, etc.—*R. E. Thompson.*

Base-Exchanging Silicates for Purifying Water. Nordiske Natrolith Aktieselskab., Brit. 237, 626, July 25, 1924. From Chem. Abst., **20**: 1679, May 20, 1926. Substance suitable for removing iron, manganese, calcium, and magnesium from water is prepared by granulating clay, calcining it at 500–700° and then treating it with solution of alkali hydroxide or carbonate, e.g., boiling it for $\frac{1}{4}$ to 4 hours with solution corresponding to 1 per cent sodium oxide or 2 per cent sodium carbonate solution.—*R. E. Thompson.*

Welding Gray Cast Iron by Acetylene. F. Politz. Stahl u. Eisen, **45**: 653–8, 1925. From Chem. Abst., **20**: 1212, April 20, 1926. Thermal processes in welding gray cast iron were investigated. One end of rod, 21 mm. diameter and 150 mm. long, was heated by means of acetylene burner and temperature at various points throughout length were determined. Temperature on cooling was equalized throughout rod in 15 minutes. When end was heated to

melting point no temperature above pearlite point was recorded at 15 mm. distance. This localized heating in welding tends to set up strains which are liable to form cracks. In cold welding temperature differences in neighborhood of weld amount to about 1100°, but in hot welding whole object is heated to 900°, and differences are only about 200–250°. Except in highly strained parts, however, cold welding can be carried out without special precautions, as stresses are not so severe as generally assumed. Number of welds illustrating correct and faulty work were made and subjected to tensile and hardness tests and metallographic examination. In cold welding, structure of weld was fine-grained and contained ledeburite, but in hot welding it consisted only of pearlite and graphite. In latter case weld was softer, but withstood breaking load 50 per cent greater. Excess oxygen or acetylene, long heating, or overheating, deteriorated the weld. Addition of ferric oxide, up to 1.5 per cent, to welding powder favored formation of graphite on cooling and softened weld without reducing strength.—*R. E. Thompson.*

Preservative Coatings for Structural Materials. Rept. of Comm. D-1, Am. Soc. Testing Materials, **44**: 67 pp. (preprint) (June, 1925). From Chem. Abst., **20**: 1329, April 20, 1926. Results of tests, specifications and tentative methods of analysis. Tests seem to indicate that most rapid deterioration of paint occurs where it has been applied over badly rusted surface; sand blasting or pickling of steel seems preferable to hand cleaning. Fouling and corrosion appear to depend as much on variations in vehicle as on pigment.—*R. E. Thompson.*

Carbon Dioxide and pH Regulation of the Water by Some Fresh Water Algae. Vladimir Ulehla. Ber. botan. Ges., **41**: 20–31, 1923; Botan. Abstracts, **14**: 729. From Chem. Abst., **20**: 1647, May 20, 1926. The algae studied responded quickly to change in H-ion concentration. Rapidity of response leads Ulehla to believe that cell membrane, instead of whole protoplast, is involved in reaction. He determined pH value for different green algae and divided them into 3 classes, pH boundaries of which were narrow. The carbon dioxide and hydrogen sulfide content actually determined the algal associations. Such algae as *Cladophora* and *Oedogonium*, with narrow pH limits, existed in standing water which showed strong fluctuations in H-ion concentration. They sometimes grew on different rocks, which acted as pH regulators. *Oedogonium* with pH 7.5–7.7 grew in strongly acid water. It was covered with incrustations called Psichohormium which are formed by bacterium *Sidomonas confervarum Chol.* Latter forms slimy ring around algal cells. This bacterium produces iron carbonate and calcium carbonate, which form incrustations on algae. The carbonate dissolves with increase of carbon dioxide, freeing OH ions, thus keeping down the H-ion concentration. Ulehla calls this relation "electrical symbiosis."—*R. E. Thompson.*

Modern British Practice in Water Softening. VI. Zeolite or Base-Exchange Plants. David Brownlie. Ind. Chemist, **2**: 108–12, 1926; cf. C. A., **20**: 1479. From Chem. Abst., **20**: 1678, May 20, 1926. Following types of plants described and illustrated: (a) Boby-Azed, (b) Kennicott, and (c) Permutit.

"Doucil," used in type (a) differs from all other base exchange materials in being a colloid; it is a hard, rigid and homogeneous dried gel with approximate composition $Na_2O \cdot Al_2O_3 \cdot 5SiO_2$. Of the 13.3 per cent sodium oxide, about 10 per cent is active. Doucil is sold on 50 per cent moisture basis, and 1 ton (2240 pounds) will soften about 25,000 gallons of water of 20° hardness. "Kenzelite," used in type (b) is natural mineral zeolite. "Permutit B," used in type (c), is made from glauconite. Certain advantages are claimed for base-exchange products prepared from natural zeolites.—*R. E. Thompson.*

Washing and Sizing Sand and Gravel. Edmund Shaw. Trans. Am. Inst. Mining Met. Eng., 1926, 1528–H, 10 pp. From Chem. Abst., **20**: 1695, May 20, 1926. Review, mentioning impurities to be removed, standard washing method, and means of determining water required for washing by decantation. Special washing methods outlined.—*R. E. Thompson.*

Tremie-Placed Concrete vs. Concrete Air Cured and Then Submerged. W. S. Kinnear. Eng. News-Rec., **97**: 1048–9, 1926. Tremie-placed concrete of 1:3:6 mix when tested in compression one year after placing developed a strength ranging from 2740 to 4000 pounds per square inch, whereas concrete of same mix placed in air under almost ideal conditions developed a max. compressive strength of only 2,277 pounds per square inch.—*R. E. Thompson* (*Courtesy Chem. Abst.*).

Water-Intake Designed for Wide Distribution of Flow. Milton G. Salzman. Eng. News-Rec., **97**: 998–1002 December 16, 1926. Detailed description of "draft-distributor" type of intake for power plants which is designed to draw water from large area of body of water without unduly disturbing natural flow conditions.—*R. E. Thompson.*

Theoretical Energy Losses in Intersecting Pipes. Frank S. Bailey. Eng. News-Rec., **97**: 1087, December 30, 1926. Two misprints in formulas given in article of J. C. Stevens are pointed out.—*R. E. Thompson.*

Defense of the Price Current Meter. K. K. Hoyt. Eng. News-Rec., **97**: 1010, December 16, 1926. Discussion of Price current meter in light of recent criticism by A. Staus.—*R. E. Thompson.*

Construction of Great Water Power Plant Well Under Way. Eng. News-Rec., **97**: 1024–6, December 23, 1926. Illustrated description of progress on Conowingo hydro-electric development on Susquehanna River in Maryland, ultimate capacity of which will be 594,000 horse power. Dam is to be gravity section concrete structure approximately 4800 feet long and 104 feet high at highest point.—*R. E. Thompson.*

Treatment of Algae and Weeds in Lakes at Madison. Bernard P. Domogalla. Eng. News-Rec., **97**: 950–4, 1926. Tabulated data, illustrated graphically, of the microscopical content of the waters of the lakes at Madison, Wis., is given and the treatment of Lake Monona with $CuSO_4$ is described. Weeds

were removed by cutting and by the cable method. Arsenical compounds were found effective for destroying a variety of weeds. The study indicated that the soluble P and the different forms of N, as well as the type of bacteria present, were the growth-promoting factors for algae and weeds.—*R. E. Thompson* (*Courtesy Chem. Abst.*)

Finger Gates Control Flow of Tunnel Muck from Bunkers. Eng. News-Rec., **97**: 1044–5, December 23, 1926. Brief illustrated description of two types of finger gates employed in construction of Cascade tunnel of Great Northern Railway in Washington.—*R. E. Thompson.*

Improved Type of Copper Water Seal for Concrete Dams. C. E. Pearce. Eng. News-Rec., **97**: 1045–6, December 23, 1926. Illustrated description of improved type of seal for contraction joints in concrete dams devised during the designing of Exchequer Dam of Merced Irrigation District in California. Cost of seal installed was $2.20 per foot. This type of seal was also later used in Balch diversion dam of San Joaquin Light and Power Corporation and in Melones dam of Oakdale Irrigation District.—*R. E. Thompson.*

Heavy Rainfall and Runoff in Catskill Watershed, New York City. Wm. W. Brush. Eng. News-Rec., **97**: 1050, December 23, 1926. Data and comment on heavy rainfall and runoff in Esopus and Schoharie watershed gathering grounds as result of which it is considered necessary to use for the first time a coagulant to reduce the turbidity of the Catskill water.—*R. E. Thompson.*

Progress of Middle Rio Grande Conservancy Project. Eng. News-Rec., **97**: 904, December 2, 1926. Brief review of progress made by Middle Rio Grande Conservancy District which was organized in August, 1925, for purposes of irrigation, flood protection, drainage, river control, and water storage and distribution.—*R. E. Thompson.*

New Water Supply for Sao Paulo, Brazil, Brought 42 Miles. Eng. News-Rec., **97**: 945–6, December 9, 1926. New system now under construction for Sao Paulo has source of supply at head waters of Rio Claro, 42 miles from city and about 180 feet above distributing reservoir. Project includes 50-mile supply line consisting of 2.5 miles of tunnel, 27.5 miles concrete aqueduct and 20 miles riveted iron pipe some distance of which is in siphon, a dam impounding a lake at upper end of supply line, and a reservoir at lower end. Patent lining will be employed in pressure tunnel sections consisting of $\frac{3}{8}$ inch iron plates hydraulically pressed to form series of internally-flanged segments which can be bolted together as tunnel proceeds, forming continuous lining 8.5 feet in diameter.—*R. E. Thompson.*

Construction Methods and Plant at Martin Dam, Ala. L. G. Warren. Eng. News-Rec., **97**: 1064–71, December 30, 1926. Detailed illustrated description of plant and methods employed in construction of Martin dam and power house at Cherokee Bluffs, a storage power project on Tallapoosa River which will

create reservoir 39,400 acres in area and having capacity of 1,376,000 acre-feet for a drawdown of 60 feet.—*R. E. Thompson.*

Diagram for Flow through Venturi Meters. R. T. Regester. Eng. News-Rec., **97**: 716–7, 1926. A diagram is given showing the relation of head to water flow for standard Venturi meters.—*R. E. Thompson* (*Courtesy Chem. Abst.*).

Dolgarrog Dam Failure Blamed on Poor Foundation and Concrete. Eng. News-Rec., **97**: 873, November 25, 1926. Sir Alexander Gibb and Partners have reported that failure of Lake Eigiau dam was due to insufficient depth of foundations and concrete of poor quality which was not watertight. Proposals for reconstruction of reservoir include strengthening of existing wall concrete by cement grouting under pressure, reconstructing failed portion in concrete, providing reinforced-concrete facing and watertight concrete cutoff wall along whole length, providing new spillway and enlarging and concrete-paving north embankment.—*R. E. Thompson.*

Theoretical Losses in Intersecting Pipe Lines. Eng. News-Rec., **97**: 883–4, November 25, 1926. Further discussion of article of J. C. Stevens by Julian Hinds, J. C. Stevens and Harold A. Thomas.—*R. E. Thompson.*

Serial Numbers on Fire Hydrants. Samuel P. Baird. Eng. News-Rec., **97**: 884, November 25, 1926. Suggestion that hydrants should be marked with serial number to facilitate identification.—*R. E. Thompson.*

Velocity at Tangent of Curves of 36-Inch Pipe. T. Farrance Davey. Eng. News-Rec., **97**: 905, December 2, 1926. Tests made to determine values of coefficient—mean average velocity divided by center velocity—for 36-inch reservoir discharge pipe under head of 80 feet at point of tangency of two curves (one reverse of other) showed that variation of coefficient from mean average coefficient was inappreciable, being 0.33 per cent over range of flow from 2 to 6 feet per second.—*R. E. Thompson.*

New Water Softening Plant for Hinsdale, Illinois. Frank D. Danielson. Eng. News-Rec., **97**: 780–2, 1926. Illustrated description of softening and recarbonation plant at Hinsdale consisting of mixing tanks providing 20 minutes retention, clarifying basin equipped with Dorr clarifier providing 1 hour retention, settling basin providing 8 hours retention, carbonation basin, filters, and storage reservoir. Treatment of 1000 gallons of water requires 2.8 pounds $Ca(OH)_2$, $\frac{2}{3}$ pound 58 per cent Na_2CO_3 and $\frac{1}{8}$ pound alum. Chemicals are added in the mixing tanks, and sludge from clarifier is returned to these tanks also. Average total hardness is reduced from 472 to 100–130 p.p.m. CO_2 is produced by combustion of illuminating gas, 550 pounds per million gallons being applied, requiring 7,500 cubic feet of illuminating gas. Average cost of softening and carbonation is 6 cents per 1000 gallons. Initial cost of plant, which has nominal capacity of 2.3 m.g.d. and maximum capacity of 3 m.g.d., was $102,000.—*R. E. Thompson* (*Courtesy Chem. Abst.*).

Slide Rule for Submerged Orifices and Cipolletti Weirs. H. K. SMITH. Eng. News-Rec., **97**: 512–3, 1926. A brief description.—*R. E. Thompson (Courtesy Chem. Abst.).*

Do Baffle Piers Dispel Energy? Eng. News-Rec., **97**: 800–2, November 11, 1926. Discussion of paper of I. C. STEELE on this subject by ROBT. E. EWALD and reply to same by I. C. STEELE.—*R. E. Thompson.*

Differing Views on Use of Water Supply Reservoirs for Recreation. M. M. O'SHAUGHNESSY. Eng. News-Rec., **97**: 802, November 11, 1926. Condemnation of practice of employing water reservoirs for recreation.—*R. E. Thompson.*

Balch High-Head Power Project Well Under Way. Eng. News-Rec., **97**: 836–9, November 18, 1926. Illustrated description of progress on Balch hydroelectric development on Kings River in California. Project is first of series of 9 plants to be built by San Joaquin Light and Power Corporation on two branches of river to develop 500,000 h.p. from total head of 7,290 feet. Series of plants will involve 4 reservoirs, 14 dams, and 40 miles of conduit, chiefly in form of pressure tunnels. Balch plant will operate under head of 2243 feet (2381 feet static). Until Bucks Creek plant (2552 feet head) of Feather River Power Co. is completed this will be highest head plant in United States.—*R. E. Thompson.*

Tests of Large Riveted Joints of Various Steels. Eng. News-Rec., **97**: 864, November 25, 1926. Results of tests carried out at Bureau of Standards, reported by E. L. GAYHART, lead to conclusion that rivets softer than plate are better than rivets of equal strength or stronger, and that slip occurs at lead corresponding to about half usual rivet stress, or at shear of about 6,500 pounds per square inch.—*R. E. Thompson.*

Puddle Core Investigations at Tieton Dam, Washington. IVAN E. HOUK. Eng. News-Rec., **97**: 544–7, September 30, 1926. Results given of detailed core investigations made by Bureau of Reclamation during construction of Tieton hydraulic-fill on Yakima project. Details of methods included.—*R. E. Thompson.*

Structures on a Texas Water Service District. J. L. LOCHRIDGE. Eng. News-Rec., **97**: 748–51, November 4, 1926. Description of supply system of Wichita County Water Improvement District No. 1, completed in 1925, which was constructed primarily for water supply of Wichita Falls, Texas, but which provides sufficient water to irrigate about 100,000 acres along Wichita River and Holliday Creek. Construction of diversion dam and head works, canals, etc., described and illustrated.—*R. E. Thompson.*

Experimental Arch Dam Under Test Shows Anomalous Distortion. Eng. News-Rec., **97**: 828, November 18, 1926. Brief details given of results of tests of Stevenson Creek experimental arch dam of Engineering Foundation.—*R. E. Thompson.*

Gasoline Fire Used to Remove Cement Plaster in Reservoir. E. R. Oden. Eng. News-Rec., **98**: 495, March 24, 1927. Following unsuccessful attempt to stop leakage in concrete lined storage reservoir by applying thin troweled lining of cement over entire floor, it was decided to waterproof reservoir with "aquatite." It was found however that if cement plaster was not removed before coating with "aquatite," bulging occurred in heat of sun. Plaster was removed by flushing with gasoline and igniting, 90 per cent being removed at first firing and remainder at second. Gasoline used was 1 gallon per 75 square feet. Work was done without injury to old concrete.—*R. E. Thompson.*

Special Carriage Handles Penstock Sections on Steep Slope. Daniel McFarland. Eng. News-Rec., **98**: 498, March 24, 1927. Brief description of carriage in use on Kings River development of San Joaquin Light and Power Co., for handling sections of penstock pipe, grades on which are as much as 119 per cent.—*R. E. Thompson.*

Buried River in Illinois Furnishes Ground-Water Supply. W. D. P. Warren. Eng. News-Rec., **98**: 398–9, March 10, 1927. New 2-m.g.d. supply of Sullivan, Ill., derived from two 115-foot wells in buried, gravel-filled, preglacial valley of Kaskaskia River. Daily requirements for population of 2,500 is 250,000 gallons. Total cost was $210,000 and it is estimated that equal supply of surface water would have cost more than $1,000,000.—*R. E. Thompson.*

A Simple Water Aërator. James L. Barron. Eng. News-Rec., **97**: 634, 1926. Brief illustrated description of aërator consisting of inverted V-stack of horizontal staggered baffles which provide a cascade for the water, giving an even distribution and fine separation of flow. The aërator requires about 8–9 feet additional pumping head.—*R. E. Thompson* (*Courtesy Chem. Abst.*).

Los Angeles Flood Control. Eng. News-Rec., **98**: 62, January 13, 1927. Work has been actively under way on several dams, notably Pacoima dam, an arched concrete structure to be 375 feet high. Other structures under way are Santa Anita dam, Sawpit dam, and Puddingstone earth-fill dam.—*R. E. Thompson.*

American Falls Dam. Eng. News-Rec., **98**: 63, January 13, 1927. This dam is being built at American Falls on Snake River in Idaho to store water for irrigation. Dam is 4,756 feet long and 60 feet high, made up of concrete overfall and plain gravity sections and earth embankments. Storage capacity provided is 1,700,000 acre-feet. Dam is practically completed and storage of water was begun in October. Cost will be about $1,600,000.—*R. E. Thompson.*

Coolidge Dam. Eng. News-Rec., **98**: 63, January 13, 1927. Coolidge dam on Gila River in Arizona, being constructed for storage of irrigation water, is to be of new type called "multiple dome," 249 feet high and about 600 feet long, made up of 3 arch spans curved both horizontally and vertically. Contract was awarded December 2 for $2,268,525. Storage of about 1,300,000 acre-feet will be provided.—*R. E. Thompson.*

Conowingo Dam. Eng. News-Rec., **98**: 63, January 13, 1927. Brief review of progress on 4,800-foot dam and power house being built near mouth of Susquehanna River by Susquehanna Power Co.—*R. E. Thompson.*

How to Proportion Concrete Mixtures of a Desired Strength by the "Water-Ratio" Method. A. T. Goldbeck. Cont. Rec., **40**: 968, 1926. Table is given showing the water-cement ratio required for concrete of various compressive strengths and practical proportioning procedure outlined.—*R. E. Thompson (Courtesy Chem. Abst.).*

Hetch Hetchy Water. Eng. News-Rec., **98**: 62, January 13, 1927. Work was completed early this year on San Francisco Bay crossing division with total of 21.8 miles of aqueduct, chiefly 60-inch steel pipe. Sixteen miles of tunnel are now under way. There is a gap of about 75 miles of tunnel and pipe line on which no work has been started. Estimated that first Hetch Hetchy water can be delivered to San Francisco peninsula in 1931.—*R. E. Thompson.*

Mokelumne Water Supply. Eng. News-Rec., **98**: 62, January 13, 1927. Some 27 miles of 65-inch pipe line have been completed and work is progressing, or has been completed, on approximately 19 miles of tunnels and other structures between Oakland and San Joaquin River crossing. Contract for Pardee dam at Lancha Plana site on Mokelumne River has been awarded. Work on remaining 46 miles of steel pipe aqueduct east of San Joaquin River is expected to start early in 1927 and delivery of Mokelumne River water into Oakland storage reservoirs is expected in 1929.—*R. E. Thompson.*

Los Angeles Water Supply. Eng. News-Rec., **98**: 62, January 13, 1927. Additional sources of supply in Owens Valley available for use in Los Angeles are being developed to supplement present Owens Valley aqueduct. Engineering studies are being made regarding construction of proposed aqueduct that would bring 1,500-second-foot supply from Colorado River, a distance of 268 miles, chiefly through desert country.—*R. E. Thompson.*

Boston Water Supply. Eng. News-Rec., **98**: 64, January 13, 1927. Progress briefly reviewed. Work is in charge of special body known as Metropolitan District Commission. Borings are in progress on line of Ware River tunnel and at sites of dams for proposed Swift River reservoir, authority to construct which has not yet been specifically granted. Ware River tunnel will be $12\frac{3}{4}$ feet in diameter and 12 miles long.—*R. E. Thompson.*

Tank Tower Wrecked by Twisting after Removal of Diagonals. Eng. News-Rec., **98**: 121, January 20, 1927. Brief description of failure of 15,000-gallon wooden tank supported on 65-foot steel tower at Peabody, Mass. In cleaning and painting tower, several diagonal rods were disconnected. A short time later the tank rotated 180° around its vertical axis and collapsed.—*R. E. Thompson.*

Price Current Meter: Serviceability *vs.* Scientific Design. GERARD H. MATTHES. Eng. News-Rec., **98**: 126, January 20, 1927. Further discussion of Price current meter in which it is pointed out that while the unreliability of this meter for turbine testing has been clearly established, it has given dependable results in stream gaging for 30 years. The meter should not be used in turbulent or eddying types of flow. Requirements of serviceable current meter outlined.—*R. E. Thompson.*

Engineering News-Record Annual Statistics of Construction Costs and Volume. Eng. News-Rec., **98**: 73–9, January 13, 1927. Review of construction in 1927, Engineering News-Record index numbers of construction cost and volume, tabulation of "spring prices" of materials, discussion of employment prospects, and table of wage rates covering 4 trades in 4 cities for 1913–1926 inclusive.—*R. E. Thompson.*

Silicates in Portland Cement. P. H. BATES. Eng. News-Rec., **98**: 121, 1927. Evidence obtained in a study at Bureau of Standards is opposed to the existence of stable ternary compound of composition $8CaO \cdot Al_2O_3 \cdot 2SiO_2$, and likewise to existence of solid solutions of silicates and aluminates in this part of the system. It is concluded that the fibre-like crystals reported by some as $8CaO \cdot Al_2O_3 \cdot 2SiO_2$ are $3CaO \cdot SiO_2$.—*R. E. Thompson* (*Courtesy Chem. Abst.*).

Hydraulic Jump Formulas. FRANK S. BAILEY. Eng. News-Rec., **98**: 126, January 20, 1927. Pointed out that equation expressing condition for critical flow, viz.: that velocity head is one-half the depth, applies only to rectangular channels.—*R. E. Thompson.*

Reproduction-Cost-New Theory. JOSEPH JACOBS. Eng. News-Rec., **98**: 33, January 6, 1927. Discussion of "reproduction-cost-new" theory of valuation, in connection with recent United States Supreme Court decision in Indianapolis Water Co. case. Reproduction cost is of importance, but should not be and usually is not accepted as final and only measure of value, nor should current prices necessarily control in determining reproduction cost.—*R. E. Thompson.*

Concentrated Flow Erodes Rock Below Wilson Dam. HUGH P. ORAM. Eng. News-Rec., **98**: 190–2, February 3, 1927. Illustrated description of erosion at toe of 100-foot and 200-foot apron extensions of Wilson Dam on Tennessee River and methods employed in correcting same. Toe of apron was undermined in places to depth of 10 feet, slabs of rock weighing 200 tons or more having been carried downstream a distance of several hundred feet. To prevent further undercutting a concrete retaining wall was built abutting toe of apron, 4 feet wide at top with batter on downstream face of 1 foot in $3\frac{1}{2}$ feet and varying in height from 6 to 14 feet.—*R. E. Thompson.*

Novel Solution of Bridgeport Dam Spillway Problem. JOHN A. BEEMER. Eng. News-Rec., **98**: 108–112, January 20, 1927. Illustrated description of

construction of Bridgeport earth dam of Walker River Irrigation District on East Fork of Walker River in Nevada. Dam, which was constructed in 1923–4, forming reservoir of 42,000 acre-feet capacity, has emergency spillway for possible one great flood in a century and working spillway for maximum flood occurring once in 2 decades. Latter is noteworthy because of its siphon type and its combination with the outlet works. Cost of reservoir of $357,000, or about $8.50 per acre-foot storage capacity. Of this, $120,000 was for lands and rights, and $237,000 for construction and overhead.—*R. E. Thompson.*

Cost of Cutting Cast-Iron Pipe by Oxy-Acetylene Flame. Scott Keith. Eng. News-Rec., **98**: 162, January 27, 1927. Brief data given on cutting of cast-iron pipe with oxy-acetylene flame during recent improvements at Fitchburg, Mass., sewage disposal plant. Cost of cutting total of 69 lineal feet averaged $1.79 per lineal foot. Found that cutting was facilitated by pricking thin tar coating and into clean metal of pipe with prick punch. Broad-tipped burner was employed. Time required to make cut 1 foot long ranged from 30 minutes at start to 15 minutes toward end of work.—*R. E. Thompson.*

Michigan Highway Water Survey. E. D. Rich. Eng. News-Rec., **98**: 186, 1927. Samples were tested from 805 sources on 5,479 miles of state road in 1926, 76.3 per cent of which were found to be safe for human consumption. Of the tubular wells, dug wells and springs examined, 79.4, 21.1, and 52 per cent respectively were found to be satisfactory.—*R. E. Thompson (Courtesy Chem. Abst.).*

Shrinkage of Hydraulic Fill for Huffman Dam. C. H. Eiffert. Eng. News-Rec., **98**: 145, January 27, 1927. Average shrinkage recorded in observations extending over 5½ years is 0.51 per cent. Settlement of foundation considered negligible.—*R. E. Thompson.*

Developing Power on the Gatineau. Eng. News-Rec., **98**: 151–3, January 27, 1927, 194–8, February 3, 1927, and 234–41, February 10, 1927. Detailed description of 400,000-h.p. hydro-electric development on Gatineau River in Quebec, comprising 3 power plants and a group of storage dams. Construction of latter described and illustrated.—*R. E. Thompson.*

Water Supply System at Belle River. Contract Record, **40**: 1115–6, November 24, 1926. Brief illustrated description of recently completed water works system of Belle River, Ont., consisting of intake in Lake St. Clair, 175-g.p.m. pressure filter, chlorinator, and centrifugal pumps. Population supplied is 900. House services are of copper and are unmetered. Total cost of plant was $75,000, and cost of water per house is $27 per year.—*R. E. Thompson.*

Water Gain and Allied Phenomena in Concrete Work. Herbert J. Gilkey. Eng. News-Rec., **98**: 242–4, 1928. Water gain, or surface wetting of concrete, is believed to be result of a downward movement of heavier solids, not unlike any other sedimentation process in its latter stages. This results in weaker

concrete at surface of mass. Contention is confirmed by fact that failure usually occurs in upper portion of test cylinders. Moreover, particles of coarse aggregate invariably adhere more tenaciously to mortar above them than to mortar below, owing to the gathering of moisture and air bubbles on underside of stones, which weakens the bond.—*R. E. Thompson* (*Courtesy Chem. Abst.*).

Typhoid Deaths in U. S. in 1925. Eng. News-Rec., **98**: 233, February 10, 1927. Brief data from Public Health Reports, January 7, 1927. Average death rate was 9 per 100,000 for population estimated as of July 1, 1925, at 111,344,000 (two states not reporting). Total deaths in 46 states, including District of Columbia, was 9,726. For 22 states rate was 5 or less and for 6 states it was 20 or more.—*R. E. Thompson.*

Large Portable Belt Conveyor Handles Reservoir Excavation. Eng. News-Rec., **98**: 247, February 10, 1927. Brief illustrated description of 36-inch belt conveyor employed for moving 150,000 cubic yards of earth over 33-foot walls of reservoir under construction at new water works of St. Louis, Mo. Conveyor handled 800 $1\frac{1}{4}$-yard loads per 10 hours.—*R. E. Thompson.*

A Small Hydro-Electric Plant in Utah Rehabilitated. Eugene Schaub. Eng. News-Rec., **98**: 276–9, February 17, 1927. Illustrated description of reconstruction of hydroelectric plant of Logan, Utah, on Logan River.—*R. E. Thompson.*

Steamed-Cured Cylinders Give 28-day Concrete Strengths in 48 Hours. M. S. Gerend. Eng. News-Rec., **98**: 282–3, 1927. A method of testing concrete is described in which specimens after an initial set of 24 hours at room temperature are placed together with a pilot cylinder of known 28-day strength in a saturated steam bath at 80–100 pounds pressure for 12 hours, allowed to cool, and tested in compression. The strength can be computed from proportion of 28-day strength developed in pilot test cylinder under conditions of test. Variations in predicted 28-day strength from that actually found in tests of 20 specimens picked at random averaged 5.25 per cent. The discrepancies in forecast should not exceed 250 pounds, with average difference of not over 100 pounds.—*R. E. Thompson* (*Courtesy Chem. Abst.*).

Cost of American Falls Dam. Lester C. Walker. Eng. News-Rec., **98**: 292, February 17, 1927. Pointed out that while cost of dam will be $1,600,000 cost of reservoir will be about $8,000,000 or $5 per acre-foot. Difference in cost of dam and reservoir is due to expensive right-of-way, necessity of moving whole town, settlement for water rights, etc.—*R. E. Thompson.*

Vertical Steel Net Protects Intakes at Lake Cushman Dam. Eng. News-Rec., **98**: 249, February 10, 1927. Brief illustrated description of net of No. 6 welded galvanized wire mesh 6 inches square, suspended by means of 1-inch cable, which was stretched in vertical plane a short distance from upstream face of Lake Cushman dam to protect intakes from waterlogged timbers or other objects.—*R. E. Thompson.*

Figuring Velocity of Approach in Dam Design. Hardy Cross. Eng. News-Rec., 98: 500, March 24, 1927. Brief discussion of kinetic pressure due to velocity of approach. Effect is small and is decreased by eddy losses.—*R. E. Thompson.*

Layout of Accessory Equipment in Modern Swimming Pool. J. Frederick Jackson. Eng. News-Rec., 98: 232–3, 1928. Brief illustrated description of a 60- by 25-foot pool in New Haven, Conn. Water purification equipment consists of 42-inch pressure filter and automatic apparatus for application of alum and bleaching powder.—*R. E. Thompson (Courtesy Chem. Abst.).*

Rio Grande Development Project in New Mexico. R. G. Hosea. Eng. News-Rec., 98: 400–1, March 10, 1927. Plans and progress made by Middle Rio Grande Conservancy District on project for systematic irrigation, land drainage, and flood protection over distance of 150 miles on Rio Grande outlined.—*R. E. Thompson.*

Iowa Flood of Cloudburst Type Damaged River Structures. E. W. Dunn. Eng. News-Rec., 98: 405–6, March 10, 1927. Data given on flood in Sioux County resulting from heavy rainfall on September 17, 1926.—*R. E. Thompson.*

Erecting a High-Head Penstock on the Balch Project. Eng. News-Rec., 98: 406–9, March 10, 1927. Illustrated description of construction of penstock on Balch project of San Joaquin Light and Power Corporation, which has static head of 2381 feet. Penstock, which is 4882 feet in length, was constructed of 40- to 60-inch banded pipe, fabricated in Poland, consisting of forge-welded core over which steel bands are shrunk. Joints are of single- and double-riveted bump types, double-riveted butt-strap and flanged. Two coats of tar paint were applied at factory and pipe was touched up after erection. Lower 250 feet of line was embedded in concrete.—*R. E. Thompson.*

New York to Build 4 Miles of Shield Tunnel Under Difficult Conditions. Eng. News-Rec., 98: 328–31, February 24, 1927. Details of two-tube tunnel, 9104 feet in length, to be driven through fine sand under East river.—*R. E. Thompson.*

Ten-Inch Wood Stave Pipe Line has Suspended Span 275 Feet Long. Eng. News-Rec., 98: 162–3, January 27, 1927. Brief description of 10-inch wood-stave pipe line which was suspended across canyon on 1-inch steel cables during construction of Lake Cushman Dam for Tacoma, Wash. Little sagging occurred when line was subjected to pressure of 175 pounds per square inch.—*R. E. Thompson.*

Equipment Worth $1000 per Man Employed in Rush Earth-Fill Dam Job. Eng. News-Rec., 98: 334–5, February 24, 1927. Brief details of equipment and methods employed in construction of Philbrook dam, a rolled earth fill, for Pacific Gas and Electric Co., on west branch of North Fork of Feather River. Dam is 90 feet high and contents total 142,000 cubic yards. Capacity of

reservoir is about 5000 acre-feet, which will be employed for storage for power development. Equipment employed was valued at $1,000 per man. Crew of 125 men moved average of 2500 and maximum of over 3,000 cubic yards per day. —*R. E. Thompson.*

Economic Diameter of Water Pipe Lines. Eng. News-Rec., **98**: 499–500, March 24, 1927. Mathematical discussion of paper of J. W. Ledoux by Ralph W. Powell and reply to same by J. W. Ledoux.—*R. E. Thompson.*

Water Rates of Milwaukee Upheld by the Wisconsin Railroad Commission. Eng. News-Rec., **98**: 451–3, March 17, 1927. Uniform meter rate for all water sold by Milwaukee water works within city and higher, but also uniform, rate for metered water sold outside city has been approved by Railroad Commission of Wisconsin. Commission holds that there is wide range between what large and small consumers actually pay for water owing to fact that first cost of main extensions, service connections, and meters is met by meter users and meter charge is same for all consumers. Commission also approves fire protection charge of $10 per hydrant paid by city, although holding that revenue thus afforded does not equal cost of providing and maintaining hydrants alone without making allowance for capital and operating costs of mains and pumping stations. Water works as whole is not giving proper return on investment. Commission bases its approval on its opinion that as rates are not excessive, unjust, or unjustly discriminatory, city is entitled to exercise managerial discretion as to what rates shall be.—*R. E. Thompson.*

Soft Ground Tunneling Methods for Small Sewer. Eng. News-Rec., **98**: 478–9, March 24, 1927. Brief details are given of construction of 48-inch sewer nearly 1-mile long, mostly in tunnel, at Akron, Ohio. Both cap-and-leg and cant-and-shield methods of tunneling were employed.—*R. E. Thompson.*

Gunite Repair of 36-Inch Pipe Line. Ralph G. Wadsworth. Eng. News-Rec., **98**: 496–7, March 24, 1927. Description of repairing of 36-inch riveted-steel pipe line which had been rendered unserviceable by electrolytic action, by applying $1\frac{1}{2}$-inch lining of gunite. Contract was for 5200 feet of pipe at 2.35 per lineal foot, total cost being only about half estimated cost of replacement. Manholes were constructed at intervals of 250 feet. After work was well organized, average of 100 feet of pipe was lined each 10-hour day with 1 gun.—*R. E. Thompson.*

Density of Concrete and the Water-Cement Ratio. F. R. McMillan. Eng. News-Rec., **98**: 445–7, 1927. Graphically illustrated discussion of relationship of water-cement ratio to density and permeability, which leads to conclusion that to be watertight, concrete must be placed in plastic condition, must have a low water-cement ratio, and must be thoroughly cured. In computing the amount of solid matter (density), the quantity of combined water should be added to the absolute volumes of cement and aggregate. The imperviousness is determined by the amount of free or uncombined water.—*R. E. Thompson* (*Courtesy Chem. Abst.*).

Annual Yield of Driven Wells at Lowell, Mass. Robt. J. Thomas. Eng. News-Rec., 98: 369, March 3, 1927. Tabulated data given showing annual yield of driven wells from which Lowell has obtained its water supply for 32 years. Construction cost of well supply, $700,000, was lower than for surface supply, but cost of pumping is high as water has to be pumped twice. Cost of pumping and filtering last year was $50 per m.g. Supply is just adequate and as further ground water is unobtainable, State Department of Health is now advising that surface supply be developed.—*R. E. Thompson.*

In Defense of Current Meters. Benjamin F. Groat. Eng. News-Rec., 98: 370, March 3, 1927. Further discussion of current meters with tabulation showing comparison of turbine discharges determined by means of 3 types of current meters and by chemical method. If extreme accuracy is required, as in turbine testing, it is necessary to employ more than one type of meter, unless most unusual conditions of quiet flow exist, as in long, straight, uniform canals. Meters of cup type over-register in turbulent flows while those of propeller type under-register, and discrepancy is criterion of degree of error.—*R. E. Thompson*

Conditions and Prospects on the Colorado Delta. Eng. News-Rec., 98: 439–44, March 17, 1927. Three articles, as follows: 1. **Imperial Valley Views on the Colorado Delta Situation.** 2. **Channel and Levee Conditions on the Colorado Delta.** R. M. Priest. 3. **Colorado Delta Silting Causes Serious Flood Menace.** J. C. Allison.—*R. E. Thompson.*

Heavy Autumn Rainfall in Illinois in 1926. Clarence J. Root. Eng. News-Rec., 98: 327, February 24, 1927. Data given on severe rains and widespread flood conditions throughout central Illinois, supplemented by information in paper from office of Pearse, Greeley, and Hansen. Comparison of 5-day rainfall and 10-day runoff given in latter indicates that for Mackinaw River the discharge was 6.68 inches and the rainfall 15 inches, while on Sangamon River the respective figures were 7 and 20 inches.—*R. E. Thompson.*

Echo Reservoir to be Built. Eng. News-Rec., 98: 355, March 3, 1927. Weber-Provo reclamation project in Utah has been approved and construction will be proceeded with. Central feature is 74,000-acre-foot (Echo) reservoir on Weber River. Dam will be earth embankment of 125 feet maximum height and 1800 feet length, containing 1,400,000 cubic yards of material, with water face riprapped 4 feet thick. A 25-mile upstream canal will be excavated from the Weber to the Provo River to enable diversion of water from reservoir into latter river to increase low-water flow. Cost will be $3,000,000.—*R. E. Thompson.*

Tentative Conclusions from Arch Dam Test at Stevenson Creek. Eng. News-Rec., 98: 450, March 17, 1927. Brief tentative conclusions.—*R. E. Thompson.*

Charts Check Costs and Progress in Dam Building. Dan Patch. Eng. News-Rec., **98**: 480–1, March 24, 1927. Description of cost and progress charts developed by author.—*R. E. Thompson.*

ABSTRACTS, SUB-COMMITTEE NO. 9

Joint Research Committee on Boiler Feedwater Studies

Experience and Progress in Treatment of Boiler Feedwater (Neuere Erfahrungen und Fortschritte in der Behandlung des Kesselspeisewassers). E. Gutmann. Dinglers polytechnisches Jl., **108**: 3, February, 1927, pp. 29–31. Points out that one of newest and most noteworthy means of preventing boiler scale is known under trade name of Kespurit, which has been in successful use for several years; it is water-soluble colloid enveloping smallest scale-forming constituents, which are thus prevented from wandering as insoluble colloids in boiler.

Principal Methods of Boiler-Feedwater Treatment (Kritik der hauptsächlichsten Methoden zur Reinigung von Kesselspeisewasser). Wärme- u. Kälte-Technik, **29**: 4, February 23, 1927, pp. 46–50. Discusses Permutit, lime-soda, and Neckar processes.

Thermal Methods of Feedwater Treatment (Die thermische Speisewasseraufbereitung). R. Blaum. V. D. I. Zeit., **71**: 9, February 26, 1927, pp. 285–290, 12 figs. Exhaust-steam evaporator makes no additional demand on boiler and heat content in evaporated steam as regained in feedwater preheater; under these conditions, evaporator ceases to be emergency device and becomes regular element of power plant; author recommends two-stage preheating; in one stage auxiliary steam is available at high pressure, and other at low pressure; degasification of water can be best carried out in mixed preheaters; under land installations most important factor to be consideied is very large scale of operation; heat loss in central stations can be kept good deal below that on shipboard; author shows that it is possible to find proper solution for problem of water distillation, whether boiler is equipped with economizers or regenerators and air preheaters; described central-station installation where bled steam is used for heating and water raised to temperature of 65 deg. cent. See brief translated abstract in Mech. Eng., vol. 49, no. 5, May, 1927.

Overcoming Boiler-Water Troubles with Tri-Sodium Phosphate. B. C. Sprague. Power, **65**: 9, March 1, 1927, pp. 321–322, 1 fig. Sulphate waters will not cause adherent scale if enough sodium carbonate is added to maintain certain ratio between carbonate and sulphate in boiler water; at high operating pressures, however, most sodium carbonate decomposes into sodium hydroxide, making it difficult to maintain desired ratio; this difficulty can be avoided by use of tri-sodium phosphate.

Boiler Scale and Its Prevention (Sur un cas d'incrustation des chaudières alimentées avec de l'eau épurée et le moyen de l'éviter). P. LeTellier and

H. Sunder. Chimie & Industrie, 16: 3, September, 1926, pp. 241–242. Describes process of treating feedwater by replacing adequate quantity of sodium phosphate by phosphoric acid.

Apparatus for Deaërating Boiler Feed Water. W. S. Elliott. Brit. 247,342, Dec. 18, 1924. Chem. Abst., February 20, 1927, 21: 4, 620.

Apparatus for Treating Boiler-Feed Water. Babcock & Wilcox, Ltd., and A. Spyer. Brit. 245,664, June 16, 1925. Chem. Abst., January 20, 1927, 21: 2, 294. A de-aërator, evaporator, liming app., and filter are provided.

Bent-Tube Evaporator for Treating Sea Water for Use in Boilers, etc. R. C. Jones, U. S. 1,617,119, February 8, Chem. Abst., March 20, 1927, 21: 974.

Boiler Feedwater Treatment by Permutite System. Clarence Bahlman. Fifth Ann. Rept. Ohio Conference Water Purification. 1925, 64–7, Chem. Abst., November 10, 1926, 20: 21, 3524.—*R. E. Greenfield.*

Case of Scaling of Boilers Fed with Softened Water and Method of Preventing It. P. Le Tellier and H. Sunder, Chimie et industrie Special No., 241–3 (September, 1926). Chem. Abst., March 10, 1927, 21: 785. $CaSO_4$-bearing boiler water which had been softened (presumably in the cold) by the CaO-Na_2CO_3 processes to 4–5° of hardness (French), 0.5–2° NaOH and 3–5° total alkali, caused heavy $CaSO_4$ scaling in a boiler by reversal at high temp. of the reaction taking place in softening ($Na_2SO_4 + CaCO_3 \rightarrow Na_2CO_3 + CaSO_4$). Another water containing but little SO_4 and softened in the same manner gave but a very thin pulverulent deposit on the tubes in 1 year. Renewal of the trouble was prevented by adding 0.1 kg. $Na_2HPO_4 \cdot 12H_2O$ per cubic meter as the water was being fed to the boiler. The Ca is eliminated (presumably as $Ca_3(PO_4)_2$) in the form of a fine sludge, requiring rather frequent blow downs and occasional cleaning out of the boilers, and scaling is practically completely eliminated. To prevent the Na_2CO_3 content from rising above 0.5 g. per liter, 0.0175 liters of 45° Bé H_3PO_4 per cubic meter of water was also added.—*A. Papineau-Couture.*

Distilling Boiler Feed Water. International General Electric Co., Inc. Brit. 247,567, February 10, 1925. Chem. Abst., February 20, 1927, 21: 4, 620.

The Economy of Boiler Water Heaters in Feeding Steam Boilers. Anon. Genie civil 87: 359, 1925. Chem. Abst., July 10, 1926, 20: 2217. The apparatus of Gabarino, of Milan, is described. This app. consists of a boiler with an inner tube closed at one end into which cold feed water is fed by a delivery pipe entering the open end of the inner tube. The water is carried nearly to the closed end of the inner tube and withdrawn from the boiler after having been passed through the inner tube to its opening and then back to the other end of the boiler. Advantage is claimed for the device since any gases attack the inner tube and not the boiler and better circulation and more uniform heating result.—*Jack J. Hinman, Jr.*

Evaporator Adapted for Purifying Boiler Feed-Water. J. Price. U. S. 1,617,081, February 8. Chem. Abst., March 20, 1927, **21**: 974.

Feed Water Treatment in Power Plants. Anon. Power Plant Eng., **31**: 25–9, 1927. Chem. Abst., February 10, 1927, **21**: 3, 467. The use of evaporators with de-aërators has become general. H_2SO_4 has been successfully used to maintain the proper $SO_4:CO_3$ ratio. The use of Na phosphate has not always been satisfactory.—*K. C. Beeson.*

Modern Practices in Boiler Feed Water Treatment. A. Splittgerber, Z. angew. Chem., **39**: 1340–5, 1926; cf. C. A. **20**: 790 Chem. Abst., **21**: 4, 619. February 20, 1927. To protect the boiler from acid corrosion the alkali content should not be less than 0.4 g. per liter of caustic soda or 1.85 g. per liter of soda ash. This concentration at 200° gives a pH about 9.4 and is not injurious. Tests on well-made boilers show that rivet hole fissures are not caused by high concentration of caustic if heavy scale is not present.—*K. C. Beeson.*

Preventing Formation of Adherent Scale in Steam Boilers. R. E. Hall, U. S. 1,613,656, January 11. Chem. Abst., March 10, 1927, **21**: 786. H_2O used in steam boilers and which contains scale-forming constituents such as Ca and Mg compds. is mixed with a suitable proportion of a substance such as Na_3PO_4 which reduces the tendency to form an adherent scale in the boiler. U. S. 1,613,701 relates to a similar process in which Na_2CO_3 may be used to form non-adherent sludge.

Preventing Incrustation in Boilers. G. Bologne and W. Drybusch. Brit. 249,431, October 27, 1925. Chem. Abst., March 20, 1927, **21**: 974. Zn plates are partly immersed in the H_2O as are also battens of alder wood so that the sap may be gradually extracted from the wood.

Railroad Water Treatment. R. E. Coughlan, J. Western Soc. Eng., **31**: 392–4, 1926; cf. C. A. **20**: 3758. Chem. Abst., January 10, 1927, **21**: 2, 293. Treatment of waters with excess of lime and soda over that required to combine with scale-forming materials is satisfactory in preventing corrosion.—*K. C. Beeson.*

Recent Developments in Feed-Water Treatment. E. H. Tenney. Power Plant Eng., **31**: 23–4, 1927. Chem. Abst., February 10, 1927, **21**: 3, 467.—*K. C. Beeson.*

Recorder for Dissolved Oxygen in Feed Water. Anon. Engineering, **122**: 610, 1926. Chem. Abst., January 20, 1927, **21**: 2, 293.—*K. C. Beeson.*

Report of the Bureau of Boiler Inspection. Wm. E. Smith. Proc. Hawaiian Sugar Planters Assoc., 45th Ann. Meeting 1925, 1–20, 1926; cf. C. A. **20**: 1291. Chem. Abst., March 10, 1927, **21**: 785.—*K. D. Jacobs.*

Water Purification. A. L. Grant. Can. 258,297, February 23, 1926. Chem. Abst., November 10, 1926, **20**: 21, 3526. $BaSiO_3$ is added to heated water containing $MgCO_3$ to remove scale-forming substances from the water and avoid substitution of foam-producing or soluble salts in the water.

NEW BOOKS

Guide to Swiss Hydraulic Developments. 1926 Edition (English). Zürich, Switzerland: Secretariat of Association for Utilization of Hydraulic Power. Cloth; 6 by 9 inches; pp. 538. Reviewed in Eng. News-Rec., **97**: 1005, December 16, 1926.—*R. E. Thompson.*

Report on an Investigation of Lake Michigan in the Vicinity of South Chicago and the Calumet and Indiana Harbors. H. R. Crohurst and M. V. Veldee. Obtainable from Officer in Charge, Stream Pollution Investigations, U. S. Public Health Service, Cincinnati, Ohio. $3.40. B. coli data and brief outline of conclusions regarding pollution given in Eng. News-Rec., **97**: 1032, December 23, 1926.—*R. E. Thompson.*

Die Auskleidung von Druckstollen und Druckschacten. Otto Walch. Berlin: Julius Springer. Paper; 6 by 9 inches; pp. 188. Reviewed in Eng. News-Rec., **98**: 286, February 17, 1927.—*R. E. Thompson.*

Concrete Practice. Geo. A. Hool and H. E. Pulver. New York and London: McGraw-Hill Book Co., Inc. Cloth; pp. 369. $3. Reviewed in Eng. News-Rec., **98**: 287, February 17, 1927.—*R. E. Thompson.*

Design and Construction of Formwork for Concrete Structures. A. E. Wynn. London: Concrete Publications Ltd. Cloth; 5 by 8 inches; pp. 296. 20s net. Reviewed in Eng. News-Rec., **98**: 288, February 17, 1927.—*R. E. Thompson.*

Water Power Engineering. H. K. Barrows. New York and London: McGraw-Hill Book Company, Inc. Cloth; pp. 734. The author begins his treatment of the subject with a short sketch of the historical development of equipment for the utilization of water power. This is followed by data on the distribution of potential water power throughout the world, as contrasted with that actually developed. While the consideration of these is not absolutely essential to an understanding of the basic principles of water power engineering, the author has used them in a very interesting manner to illustrate the outstanding factors governing the usefulness of such power.

Two of the essential elements in a water power development are stream flow and available head or fall. Stream flow is subject to so many governing factors that it is apparent considerable study should be given this item. The author's treatment of this is in somewhat greater detail than usual. The principles of Hydrology, as applicable to the subject, are treated quite interestingly in Chapter II, so that the student or engineer is given a very clear picture of

the factors, in spite of the complexity of the interrelations. Chapter III deals with the correlation of stream-flow data, particularly with regard to duration curves and storage. Available head and power are also discussed in this chapter.

The fourth chapter is upon the turbine equipment and general arrangement of the plant. The trend in development of more efficient units is traced. Theoretical features of design are also considered.

In turn, the dam, waterway canals and penstocks are considered in Chapters V and VI. As affecting the location and costs, factors are given which should be covered by preliminary and final investigations, the foundation for the dam being the principal item. Various types of dams are considered with application of theoretical principles to their design. The waterways, such as canals and penstocks, are considered in much the same manner.

Chapter VII treats of the power house and its equipment. A table is included in this chapter with principal details of design of 47 different plants. Illustrations are also given of typical installations.

The electrical plant equipment is not dwelt upon in great detail; however, the essential elements are covered. Considerable space is devoted to the details of the transmission line and rightly so since it is one of the most important factors affecting the economy of the undertaking.

A separate chapter has been devoted to the theoretical elements of speed and pressure regulation. Illustrations are also included of typical regulating equipment.

The author has used quite freely examples and data in table form to support his views and conclusions. It is quite pleasing to find that the arrangement is such that the interest is held. He has devoted considerable attention to the practical and economical side. This should be appreciated since such great economies have been effected in recent years in the steam power plant field. There is no doubt that this fact will tend to an improvement in the overall cost of hydro-electric power by lessening the capital outlay, operating costs and power losses.—*Frank Quarles.*

// JOURNAL

OF THE

AMERICAN WATER WORKS ASSOCIATION

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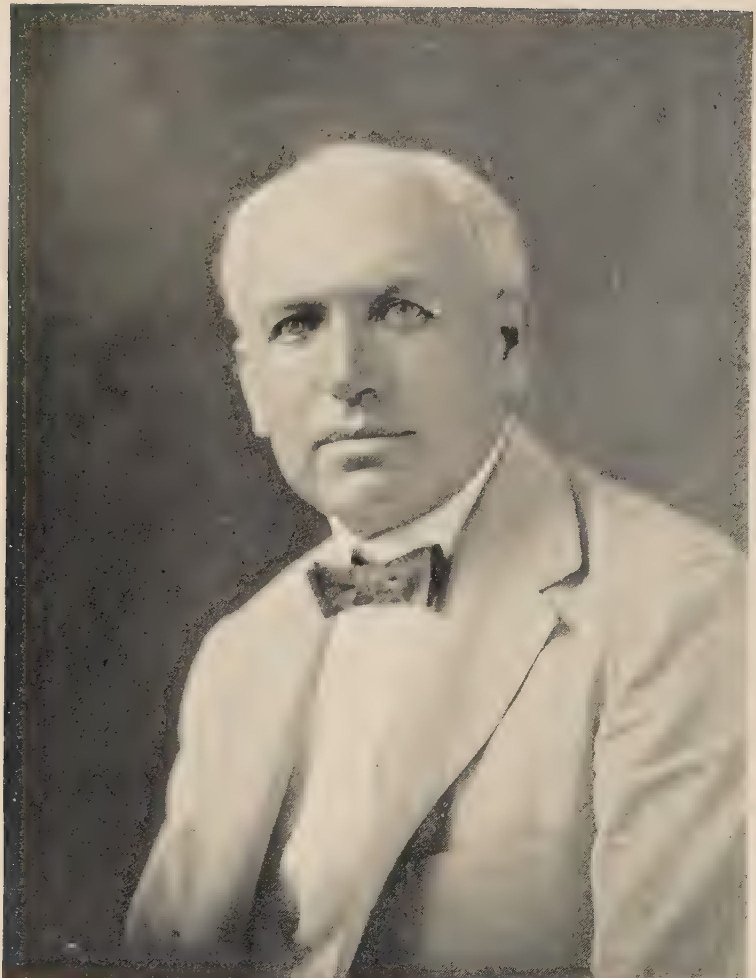

James E. Gibson, President, 1927–28

JOURNAL

OF THE

American Water Works Association

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Discussion of all papers is invited

Vol. 18 AUGUST, 1927 No. 2

A PROGRAM FOR IMPROVING THE WATER SERVICE IN CHICAGO[1]

By Myron B. Reynolds[2]

In the history of all work of large proportions I presume there is also written the history of the lives of men who have built those works. Three such men have stood out prominently in the history of the water works of Chicago. Honorable DeWitt C. Cregier devoted a long life to the service of the city. Beginning as a steam engineer, he advanced to the office of Commissioner of Public Works and later was elected to the office of Chief Executive of the city. Mr. E. S. Chesbrough was another outstanding figure. A pioneer in water works engineering, he proposed and completed Chicago's first subaqueous water supply tunnel. The last of the three was Mr. John Ericson, late City Engineer, who passed away on April 16th of this year. Arriving from Sweden in his early twenties, he entered the service shortly thereafter. In 1884, when he first took up his work in the field of water works engineering, this city had an area of 36 square miles and a population of 641,000. When he died the boundaries served by the system enclosed an area of 250 square miles and supplied water to a population of $3\frac{1}{3}$ million people. The plant had increased tenfold during his tenure of office. High tribute is paid to Mr. Ericson as a man and to his integrity as an engineer.

[1] Presented before the Chicago Convention, June 7, 1927.

[2] Acting City Engineer, Chicago, Ill.

It was to have been his honor to deliver a paper this evening on the subject of improving Chicago's water service, and it was with much reserve that I accepted your invitation to substitute for him.

CHICAGO'S WATER WORKS

Chicago's water works system at present is composed of ten pumping stations having a combined capacity of between 1000 and 1100 million gallons per day. There are 6 intake cribs and 70 miles of water supply tunnels. The diameters of these tunnels are from 5 to 16 feet, and the total capacity is between 1400 and 1500 million gallons per day. There are 3400 miles of cast iron distributing mains of sizes varying from 4 to 48 inches in diameter. When the two projects now nearing completion—the Chicago Avenue Tunnel and the William Hale Thompson Pumping Station—are put in service, the capacity of the tunnels will be 2000 m.g.d. and that of the pumping stations 1300 m.g.d.

The routine work of constructing, maintaining and operating the water works system is one of immense magnitude. The preparation of plans and designs, the writing of specifications, the awarding of contracts, and the study of the requirements of the future in our own city and the villages and towns contiguous to its boundary is a business of no small proportions. To provide water for a community which adds to its population a quarter of a million people every four years and to adjust and modify the plant to meet an ever changing character in the occupancy of its areas and sub-divisions are problems of a high technical order. When it is further considered that the promise for the future of Chicago by those whose lives have been devoted to such study is one which has seen no parallel in the history of the world, it may be well to begin thinking and planning, at once, for that future.

The present plant is in excellent condition. During the severely hot days of the summer months it has always been able to deliver water in quantities in excess of its rated capacity. Recent explorations of tunnels constructed sixty years ago show them to be in splendid condition. The same is essentially true of all parts of the system.

Inference may be drawn from the title of this paper that in some respects certain features of the service may be improved upon.

The problem of furnishing water in Chicago, as in all other cities, has always been one of supplying quantity and quality.

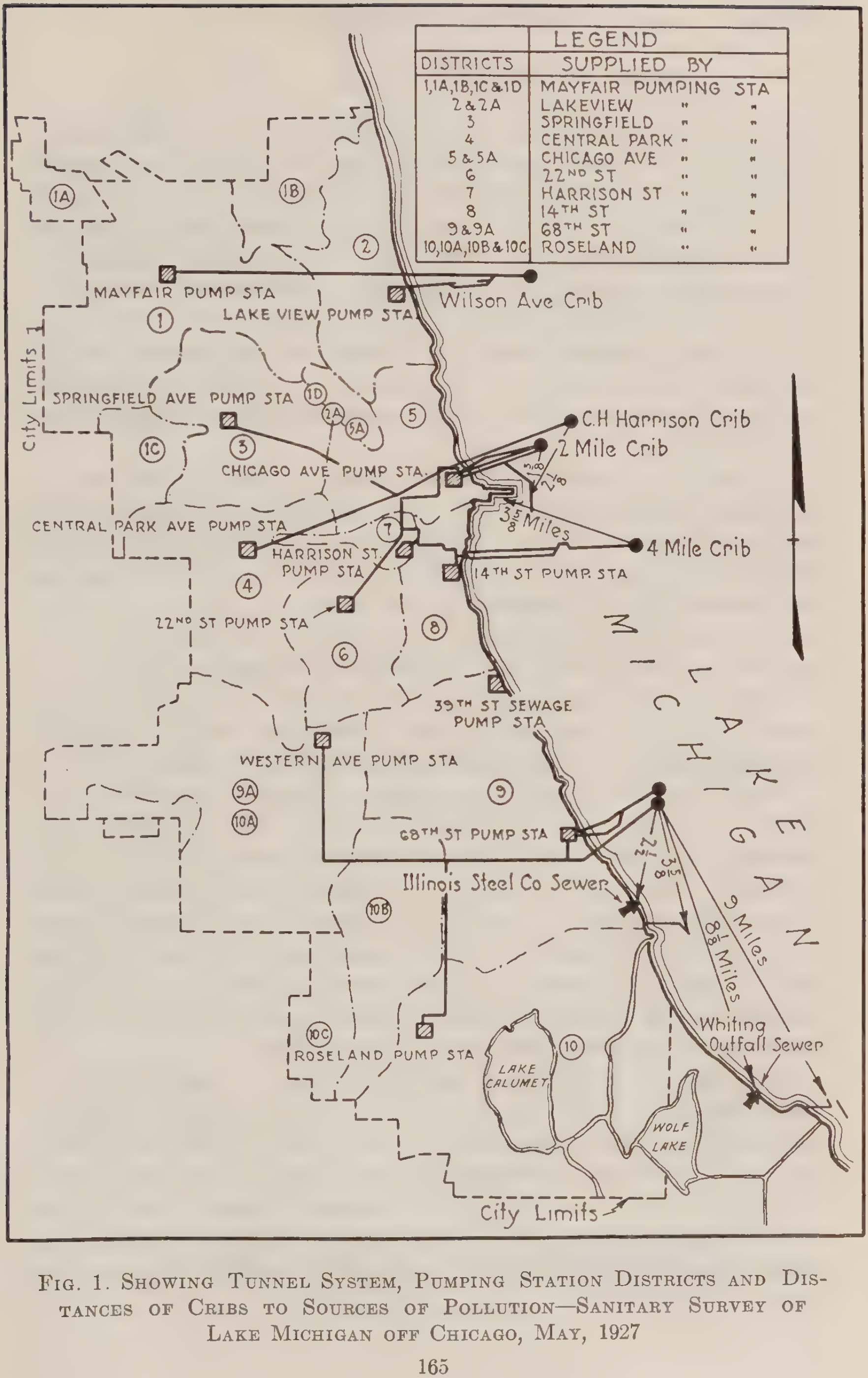

Fig. 1. Showing Tunnel System, Pumping Station Districts and Distances of Cribs to Sources of Pollution—Sanitary Survey of Lake Michigan off Chicago, May, 1927

Quantity of water

Touching first upon the question of quantity, it is particularly gratifying to be able to say that the area of the city, from which complaints of inadequate service have been received for years past, is to be relieved when the William Hale Thompson pumping station is put in operation in July of this year. This station will add 20 per cent to the present pumping capacity of the system. Its operation will be reflected in higher pressures over the entire South Side. True to past experience, however, evidences of low pressure are appearing on the far North Side and in the west central portion of the city, and appropriations may yet be requested this year to anticipate those conditions.

On June 3 of this year, at a time when pumpage should not be abnormal, pressures recorded at 9 a.m. throughout a 60 square miles area of the city were less than 15 pounds; throughout 100 square miles, between 20 and 30 pounds; and in only 40 square miles was the pressure above 30 pounds. On the same day the pumpage between 9 a.m. and noon was at a daily rate of 1050 million gallons, and between 1 and 5 a.m. at a daily rate of 730 million gallons.

While the city is not required, under the terms of its franchise, to furnish water at a specified rate or pressure, an effort is made to maintain pressures of not less than 25 pounds at the curb.

If the quantity consumed per capita per day in other cities can in any way be used as an index and if the relation of the night to day pumpage is of any value as a guide, the per capita consumption in Chicago is more than it should be. Considering the complex nature of the life and industry of the city, it probably should be more than in other cities, but, nevertheless, it appears too high, and doubtless much of the water pumped serves no useful purpose. It is felt that this is generally considered to be true and a just and equitable plan will be developed which will correct the situation.

Later this year the pumping stations will have a capacity of about 400 gallons per capita per day. The average pumpage per capita per day will be about 310 gallons. This is nearly twice that of any other city in the United States, excepting two. If, by any fair and just means, the consumption can be reduced to approximately that of other cities, Chicago has a plant which should without further outlay of capital expense for major projects be sufficient for some ten years to come.

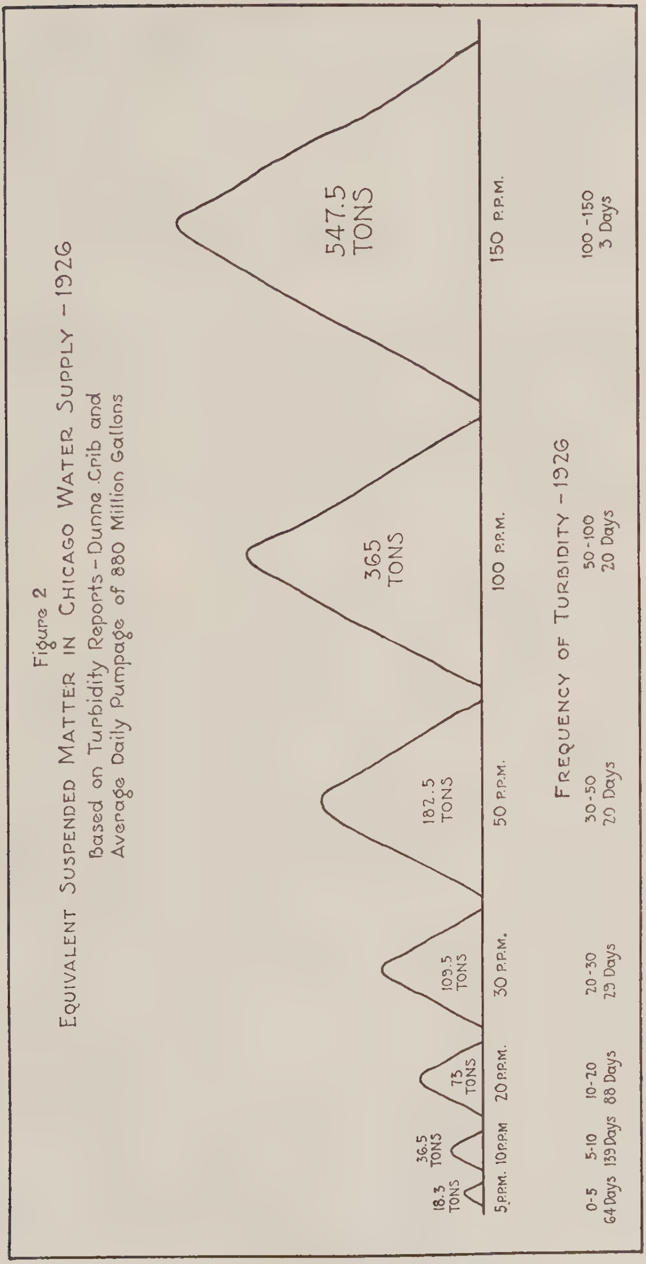

Figure 2
EQUIVALENT SUSPENDED MATTER IN CHICAGO WATER SUPPLY – 1926
Based on Turbidity Reports – Dunne Crib and
Average Daily Pumpage of 880 Million Gallons

Improving the quality of water

Perhaps the outstanding problem for the future in connection with the development of Chicago's water system is in the matter of improving the quality of the supply. In spite of the splendid work which the Sanitary District of Chicago has done in removing sewage from the lake, the water in the vicinity of our South Side intake cribs is still, during certain periods, seriously polluted by industrial wastes and sewage. Bacteriologically, the average quality of the water at the other intake cribs is of reasonably satisfactory quality, subject to occasional periods of contamination, but, as measured by present day standards, and in consideration of the development of the art of water purification, Chicago's water supply rates only as a second-class product. In other cities less favored in the matter of capacity, availability and quality of its source of supply, a safe, clean, sparkling, palatable and reasonably soft water is delivered to its homes and industries. This service was in most cases obtained at very substantial cost, but its citizens would not have it otherwise. Of all the public utilities in Chicago none is more vital or necessary to our civic and personal well being than water, but still we tolerate an inferior product.

Contrary to public opinion Lake Michigan, even free from the pollution which develops with concentration of population and industry, is not an ideal source for water used for domestic purposes. In the winter and spring months during and following storm periods on Lake Michigan the water is objectionably turbid for days and even weeks at a time from the effect of violent wave action in bringing into suspension the finely divided silt and flocculent material which settles out on the bed of the lake. A water which has a turbidity of over 10 p.p.m. has a dullness in a glass which makes it unsatisfactory as a beverage, but still during 1926 our water exceeded this degree of turbidity on 170 days. During the months of November and December of that year the average turbidity of the water from all cribs was 37.2 and 41.3 p.p.m., respectively. On the first five days of December the average turbidity was 111.6 p.p.m., which is a really dirty water even for crude purposes, to say nothing of drinking or culinary uses. In three days during this month turbidities of 200 were reported. Based on an average daily pumpage of 880 million gallons, when a turbidity of 100 p.p.m. existed in the city water, approximately 365 tons of silt are pumped with the water each day through the distribution system.

In addition to the factor of turbidity there are each year, particularly during the summer months, objectionable tastes in the water supply due to microörganisms normal to Lake Michigan water known as plankton. As the result of their physiological activities, objectionable grassy or fishy tastes are imparted to the water during periods lasting from a few days to several weeks. The diatoms, particularly astērionella, tabellāria, fragellaria and synēdra, have a very prolific growth in our water and cause thousands of citizens to register complaints against a condition which under our present system is beyond control.

Throughout the city numerous private water treatment and filtration plants are in operation in homes, hotels, apartments and industrial plants for improving the quality of the city water supply.

The initial cost of these plants plus that for maintenance and operation represents an investment of hundreds of thousands of dollars, which would be unnecessary if the city water supply were of proper quality.

Pollution of 68th Street crib

While the program of the Sanitary District is being developed adequately to dispose of the sewage of the Chicago region and to prevent gross contamination of the lake waters there still exist very serious sources of pollution of our water supply, particularly that taken in through the Dunne and 68th Street cribs, for which no definite plans for remedial measures are in sight. The most serious and dangerous polluting factors are the sewage and industrial wastes discharged into the lake from the Indiana Harbor Ship Canal, which is only eight miles southeast of these cribs. Figure 3 contained in a report on pollution of the southern end of Lake Michigan made by the United States Public Heath Service, in coöperation with the City of Chicago and the Sanitary District, shows the zones of pollution in the lake and clearly indicates that this outlet is the outstanding source of pollution of the lake south of our cribs. On both banks of this canal there are great industries discharging objectionable by-product wastes into this outlet, which under certain wind conditions may drift to our intakes within twenty-four hours. The intensely disagreeable and obnoxious iodoform-like taste which occurs in the water on the South Side not infrequently, and occasionally at other points in the city, is due to tarry acid wastes such as phenols and cresols which are discharged

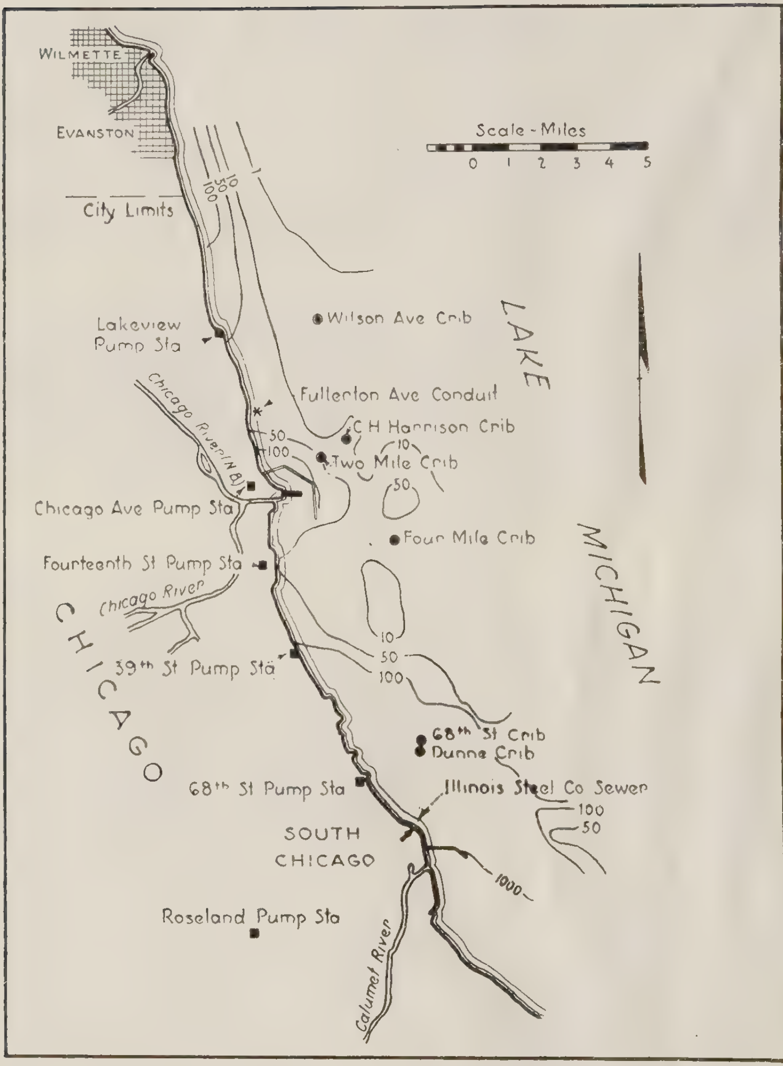

Fig. 3. Contour Map Showing Average Results B. coli per 100 cc. during a Sanitary Survey of Lake Michigan off Chicago during the Years 1924–1925–1926

into the Indiana Harbor Ship Canal. In addition to industrial wastes the sewage of approximately 250,000 people in the Calumet region is discharged into Lake Michigan in the vicinity of Indiana Harbor, grossly contaminating the water and subjecting the 800,000 people who are supplied with water taken through the Dunne and 68th Street cribs to a serious health risk. Oil wastes from the refineries at Whiting also pollute Chicago's drinking water. Even with the construction of filtration plants to purify the water for the South Side this acute taste problem will continue to exist unless measures are taken to keep these wastes out of the lake. The situation is complicated due to the fact that the sources of pollution originate in Indiana and are discharged into an interstate waterway.

Another serious source of pollution of Chicago's water supply is the 80th Street sewer from a large industrial plant. This outlet, from which sewage and plant wastes are discharged, is but $2\frac{1}{2}$ miles from the cribs and has for years been a serious factor from both a health and nuisance standpoint. With the diversion into the Harbor Avenue interceptor in September, 1926, of the sanitary sewage from a plant population of nearly 3000 employes, the public health risk was materially lessened. Studies made since that date indicate that the 80,000,000 gallons per day of waste water still discharged from this plant, and which originally was obtained from the grossly polluted North Slip, continues to contaminate the lake waters to a serious degree.

The Calumet River is the third factor which influences the quality of the water on the South Side. Records collected by the Division of Water Safety Control during the last three years indicate that this river discharges toward the lake something less than 50 per cent of the time. Fortunately, most of the sanitary sewage which formerly discharged into the Calumet River is now intercepted, but the river is still polluted by industrial wastes. Figure 4 shows the concentration of pollution which occurs outside the Calumet harbor entrance when the river discharges into the lake. Were it not for the Government breakwater which flanks the mouth of this river on the north and east, the water about our cribs would be polluted very much more from this source than it is. The plans of the Sanitary District of Chicago for increased diversion at the Sag and dredging of this river to that outlet offer a fair solution of this problem, except for acute storm periods when reversals will take place.

With an investment of about $24,000,000 in cribs, tunnels, pump-

ing stations and distribution mains served by the Dunne and 68th Street intake cribs, and with a system capable of supplying three

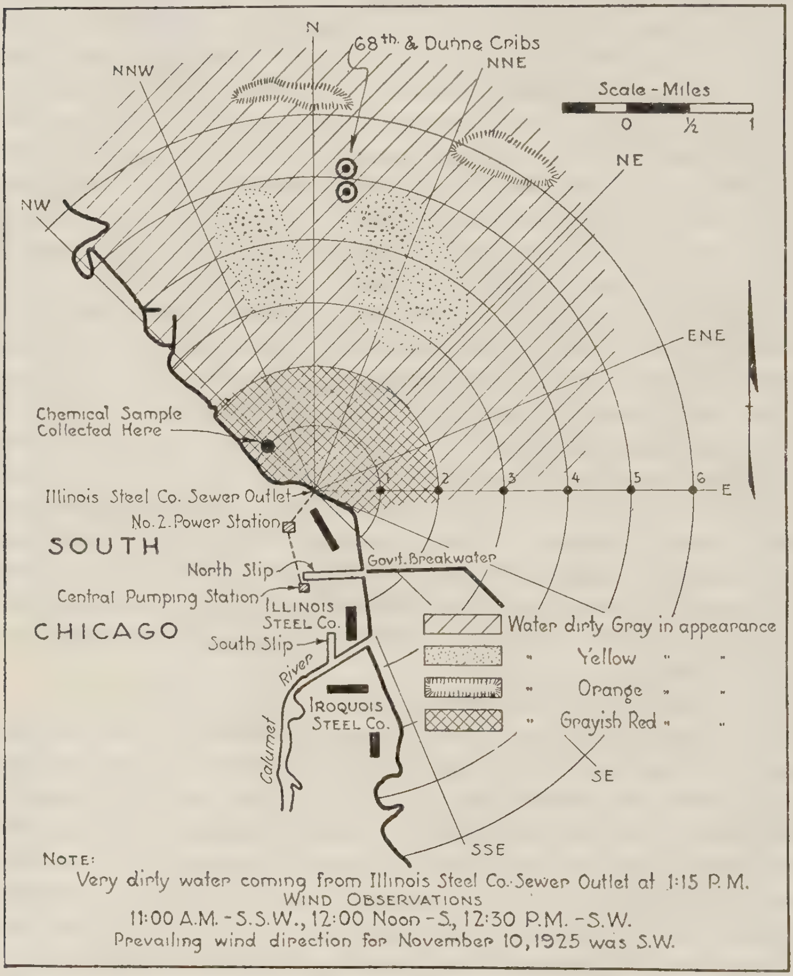

FIG. 4. AREA COVERED BY EFFLUENT FROM ILLINOIS STEEL COMPANY SEWER OUTLET—SANITARY SURVEY OF LAKE MICHIGAN OFF CALUMET RIVER, NOVEMBER 10, 1925

million people, it is imperative that a program for eliminating pollution in the southern end of Lake Michigan be adopted and aggressively carried out. As Chicago is vitally concerned and has the

potential influence necessary to prosecute such a project, it seems logical that it should take the initial step in developing a remedial program. It appears that the problem could be handled in a co-

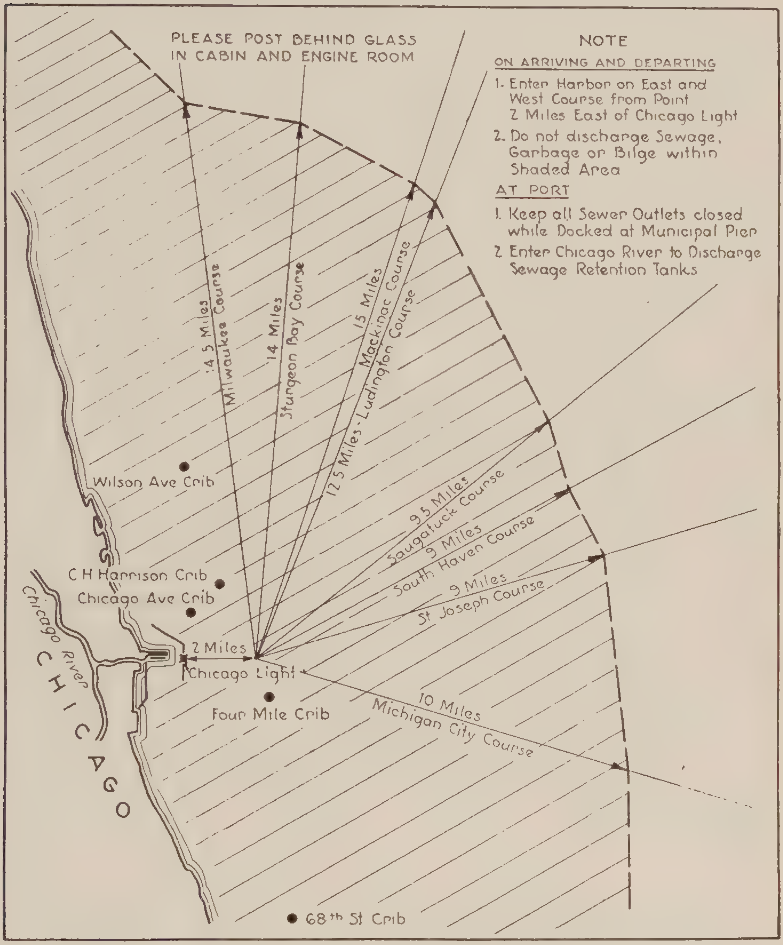

Fig. 5. Recommended Courses for Vessels Arriving at and Departing from Chicago to Avoid Contaminating the Public Water Supply

operative way between the local state and federal officials concerned, working in harmony with the industries. The United States Public Health Service, the City of Chicago and the Sanitary District have

already coöperated in making careful sanitary surveys which show the extent and effect of pollution of the southern end of the lake. What is now needed is the human machinery to work out a solution for the many local problems, coördinating these efforts to the one common end and obtaining effective enabling legislation as may be necessary.

Further pollution of the water at our intake cribs results from the discharge of wastes from vessels and the practice of dumping dredged and excavated material into Lake Michigan. The companies operating passenger vessels out of the port of Chicago have coöperated splendidly in changing the courses of boats to keep at least a mile from the crib intakes and by equipping their ships with tanks for retaining sewage until the boat is about ten miles from the cribs. The dredging and dumping situation is unsatisfactory and continues to be a potential risk and health hazard even though under supervision. As far as practical, the dumping of dredged and excavated materials is confined to points behind breakwaters built in connection with the lake front development projects, but thousand of tons of wastes of this kind are still being dumped into Lake Michigan annually either 8 or 13 miles from shore. Much of this material when dumped from scows frequently stays in suspension for several hours. On account of the shallowness of the lake that which settles to the bottom is frequently disturbed and drifted towards shore during storm periods. The inconsistency in federal and city regulations concerning dumping is worthy of note. The War Department authorized dumping grounds are 8 miles out. On the other hand, the city regulations require dumping 13 miles from shore. Accordingly, contractors for city or private work must tow scows five miles farther into the lake than is required when employed by the federal government.

Only practical solution—filtration

The only practical solution of Chicago's water quality problem is filtration. The extension of the crib intakes would not supply a satisfactory water. Our investigations show, that objectionable turbidities occur in the water as far as even 8 miles from shore during and following storm periods, and that the presence of plankton in Lake Michigan water at that distance is not materially less than in the vicinity of our present cribs. Thus, it may be seen that, in so far as turbidity and objectionable tastes are concerned, Chicago

would still have an inferior water supply using extended cribs, to say nothing of the high cost of projecting the tunnels and rebuilding the crib intakes.

The City of Chicago has during the last few years made marked progress in its program for improving the quality of the water supply. During the three years 1924, 1925 and 1926, a sanitary survey was conducted which has definitely shown the extent of pollution in Lake Michigan from various sources and the effect of storms on the lake, the influence of winds, rainfall and reversals of the rivers. From these studies and the information derived from experience with chlorination control, it is clearly apparent that filtration is a necessity, if Chicago is to have a public water supply which meets recognized standards of quality and the public health is to be adequately protected. The extent of pollution of the water in the vicinity of our South Side cribs and the rapidity with which it varies is such that continued dependence upon chlorination results in unwarranted risks. As a public health expedient disinfection by chlorine has been exceedingly valuable, even though it has been frequently necessary to use this chemical in amounts which impart objectionable tastes to the water. In spite of a very strict supervision over chlorination there were 47 periods during 1926, representing 273 hours, when the chlorine applied was very rapidly absorbed by organic matter which polluted the lake waters, lessening at least, if not seriously interfering with, the effectiveness of this chemical as a disinfectant. At such times chlorination as a purification process is greatly overloaded and the public health risks are very positive. If Chicago continues to rely solely on chlorination for safeguarding its water supply, under present conditions it is inviting a repetition of outbreaks of typhoid fever on the South Side which together cost 31 lives and caused weeks of suffering to about 340 of our citizens.

Following the findings of the lake front survey the Bureau of Engineering recommended the establishment of a water filtration research laboratory, which was equipped in the fall of 1926 at the 68th Street pumping station. The research work was undertaken with the object of obtaining fundamental data concerning the treatment of Lake Michigan water for filtration. Filter plants of sufficient size to serve the City of Chicago will probably eventually cost between 30 and 50 million dollars, and, although the art of water purification has been highly developed, it was deemed advisable, in view of the

size of the expenditure involved, to conduct preliminary research to see if any modifications might be made in standard filtration methods

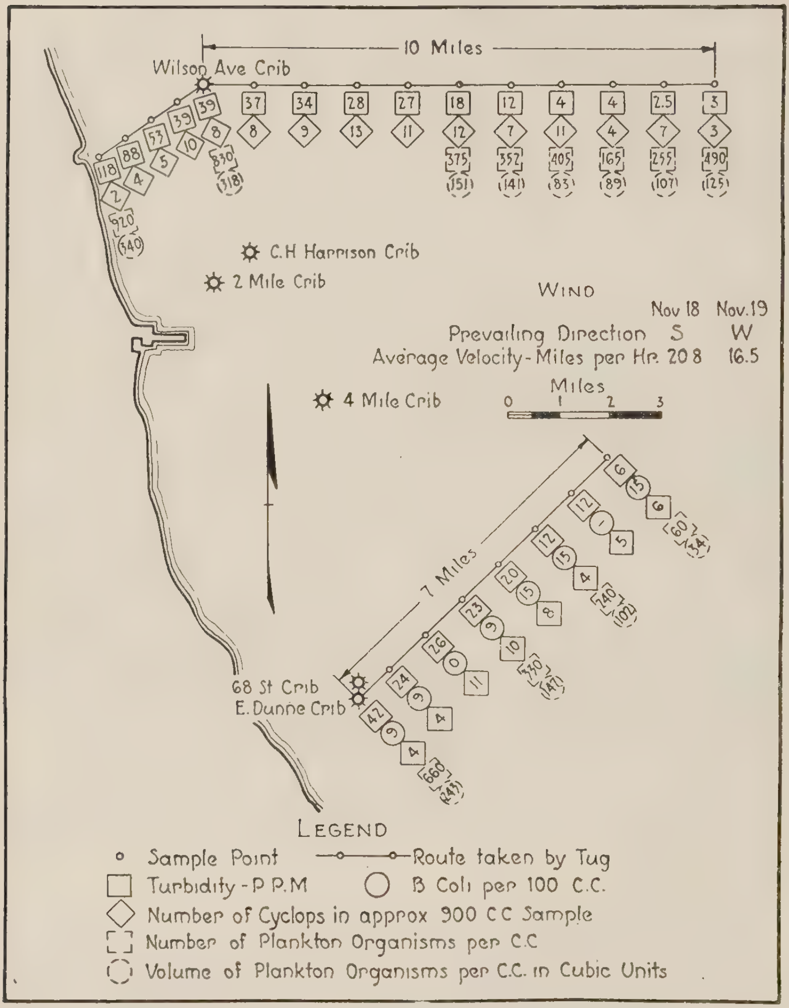

FIG. 6. RESULTS OF SPECIAL SURVEY—LAKE MICHIGAN AFTER STORM NOVEMBER 19, 1926

Tug "Lincoln Park No. 1" used in survey

which would mean the saving of large sums in the plant construction and future operation. This research to date, although only of a

preliminary nature, has indicated that there is great probability that our hopes in this direction may materialize. Therefore, an experi-

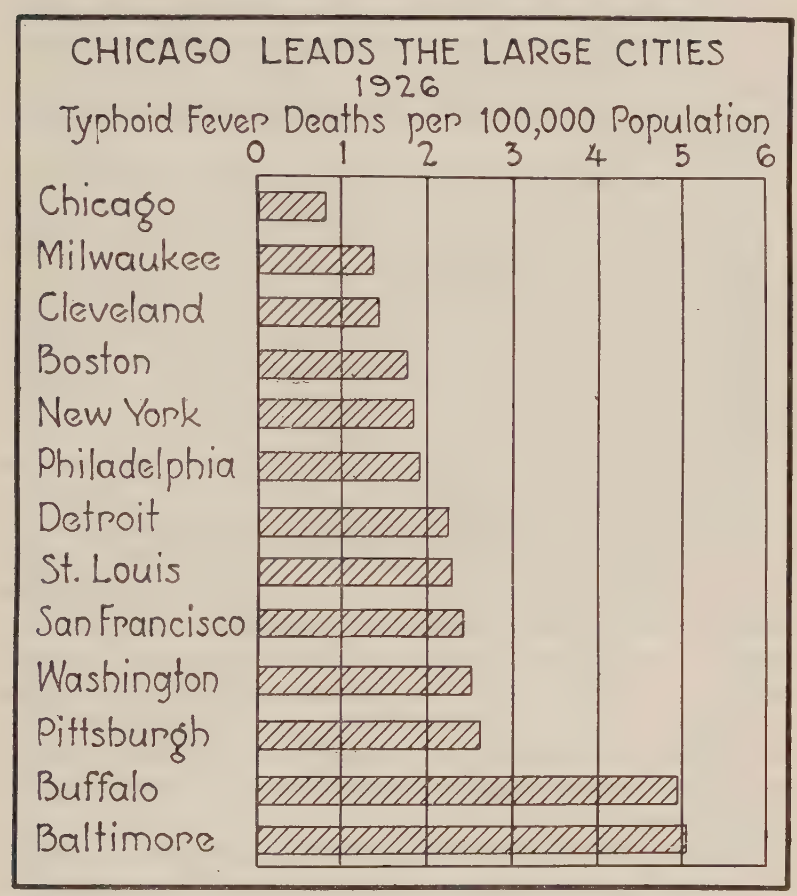

FIG. 7. THE DEATH RATE FROM TYPHOID FEVER IN CITIES OF 500,000 POPULATION AND OVER

Los Angeles is omitted from the figure because no official estimates of population are available. Estimating the population at 1,200,000 the typhoid death rate is 1.08 per 100,000 persons.

mental station has been designed and is now being constructed for making exhaustive studies on the purification of Lake Michigan water.

Experimental water filtration plant

This plant, one of the largest experimental water filtration units ever built, is being constructed at the 68th Street pumping station and will be operated under the supervision of a well known filtration engineer. We are hopeful that out of these studies will come a design for a large sized filter plant which will be novel, economical and highly efficient.

It is obvious that the first filter plants should be built to treat the water obtained from the Dunne and 68th Street cribs and our program is being developed accordingly. In order to make use of the present tunnel system and pumping stations filter plants should logically be located along the lake front. With the exception of land now and still to be developed in connection with lake front park projects, very little is available. If Chicago's filtration program is to be properly developed a working agreement should be entered into as early as possible with the Lincoln Park and South Park commissioners for filtration plant sites. While elaborate plans are being made for beautification of the lake front and the development of a system of parks and buildings for the Centennial Exposition in 1933 studies might well be made of the practicability of combining these plans with a practical program for future filtration plants. In this connection these filtration plants might well be developed, as has been suggested by the late City Engineer, John Ericson, as great centers for recreational activities, as well as for civic service. The large storage basins necessary in connection with filtration plants could be designed to harmonize with the lake front development, and the architectural design of the necessary buildings could easily be adapted to the great plan for beautification of our city.

From an engineering standpoint the fitting of filtration plants into the present Chicago water system is a major problem requiring extensive study. The balancing of the filter and storage capacity against the consumption load for an uninterrupted and economical service will require much engineering ingenuity. The financing of filter plants will require careful consideration and a plan should be developed while other phases of the project are being studied.

In the matter of finances Chicago has until recent years been able to meet all expenditures of the water works through revenues collected from the sale of water. Recently it has been necessary to issue so-called water certificates to meet a portion of the cost of new

construction. At present the outstanding debt is nominal, but it is probable that a revision of the present financial policy will be necessary when the construction of the larger work begins. The sale of long term bonds would meet the situation.

The program covering the question suggests reduction of the present pumpage, coöperation with other authorities to prevent contamination in the southern portion of the lake, provision for sites for filtration works and revision of the financial policy.

In closing a word must be said in behalf of the Water Works Tower, the emblem of the 47th Annual Convention of the American Water Works Association. The thoroughfare upon which it stands is a busy one. It has been widened on the south and widening is nearing completion on the north. The tower stands in the way of the fullest efficiency of the improvement, and its position is insecure. It is possible to move the tower westward on the same property and thereby permit widening of the boulevard for improved traffic service and at the same time preserve this historic structure for posterity. Chicago has too few landmarks which survived the great fire of 1871 and the wrecking activities which go along with progress in any great city. The old water tower is a classic of its kind and deserves this consideration.

MODERN PUMPING STATION DESIGN AND ITS PROBABLE FUTURE DEVELOPMENT[1]

By Arthur L. Mullergren[2]

Within recent years there has been quite a decided change in the design of the large modern pumping stations. This has been brought about by the increasing use of higher steam pressures and temperatures and the rapid development of the steam turbine and centrifugal pump. The present day tendencies of pumping station design are along the lines of the central electric power station. The rapidity with which improvements have been developed in the central power station has been almost phenomenal. In 1914 the average fuel consumption of several of the largest typical central power stations was 1.5 pounds of 14,000 B.t.u. coal per kilowatt hour of station sendout; today there are two of the larger stations producing electric current with 0.9 pound of coal of equivalent heat units per kilowatt hour of net station sendout. This represents a saving in fuel of 37 per cent over a twelve-year period. The various factors contributing to this saving and their relative values are about as follows:

	per cent
Increase in steam pressures and temperatures	12
Use of higher boilers with economizers, air preheaters and improvements in furnaces and combustion equipment	11
Use of electric drive for station auxiliaries	5
Use of the regenerative cycle for feed water heating	4
Improvements in turbines, condensers and auxiliaries	5

In 1914 the central stations referred to operated at a steam pressure of about 200 pounds gauge and a total steam temperature of about 500°F.; today 600 pounds steam pressure with 725°F. total temperatures are in use in a number of the typical stations, and there are two large well known central stations at present operating a portion of their equipment at 1200 pounds steam pressure.

The marked improvements made in central station design are largely responsible for the present day tendencies of large modern

[1] Presented before the Chicago Convention, June 10, 1927.

[2] Consulting Engineer, Kansas City, Mo.

pumping station designs. The water works engineers being more conservative in their views of making any material changes of existing types of equipment and improving economy at a possible sacrifice of reliability have waited until the reliability as well as economy of some of the improved power generating equipment were thoroughly established before taking any steps towards the adoption of such equipment for pumping station practice. The remarkable growth in the use of electric power has made necessary the extensive programs of power station construction, and the power station engineers have been given ample opportunities to develop the improved designs and make tests of the actual performance. After the opportunity was given the water works engineers to determine the reliability, economy and feasibility of adoption of these improved designs for water works practice, they have in the more recent large pumping stations made use of a great many of these improvements in developing the designs that meet the requirements of the particular conditions.

SLOW ADOPTION OF STEAM TURBINE

Water works engineers were at first slow to adopt the steam turbine as a prime mover, largely owing to the fact that the triple expansion pumping engine was a marvel in mechanical and thermal efficiency. As the steam pressure and temperature for this type of equipment could be increased only to a certain point, and then with but slight gain in efficiency, there was little left that could be done in the way of improving station economy. The fuel economy of a triple expansion pumping station engine is very high, and were it not for the very high first cost of this type of installation with its attendant high fixed charges, this type of plant would still be the standard for modern pumping stations. The triple expansion pumping engine costs from $2\frac{1}{2}$ to 3 times as much as the steam turbine driven centrifugal pumping unit, and the building and installation costs are considerably greater. Furthermore, the size of such units is limited to about 50 million gallons daily capacity.

With the increasing demand on the larger water pumping stations, the tendency is towards the installation of pumping units of greater capacity. There are already units installed or contracted for that have capacities in excess of 75 million gallons per day.

INCREASED EFFICIENCY OF PUMPING STATIONS

While the efficiency of the average pumping station has been considerably improved in the last twenty years, it is interesting to compare the efficiency of a large highly efficient pumping station of 1908, the California pumping station of the Cincinnati Water Works, with some of the latest types of pumping stations in use or being installed at the present time. The Cincinnati pumping station operated at a steam pressure of 150 pounds gauge and 125 degrees F. superheat, and had an economizer installed in connection with the boilers. The boilers were of the Stirling type of 2016 square feet of heating surface. The pumping units were 30 million gallon per day capacity, triple expansion crank and fly wheel engines. The superheater was separately fired and the fuel used in firing same was charged against the pumping unit. The tests conducted on this installation in October, 1908, developed the following:

Efficiency of boiler, economizer and superheater....	82.2 per cent
Mechanical efficiency of engine....................	93.3 per cent
Thermal efficiency engine..........................	22.0 per cent
Thermal efficiency plant...........................	16.375 per cent
Duty per thousand pounds steam..........	194,403,500 foot pounds
Duty per million B. T. U..................	153,500,000 foot pounds

The above performance was the best that had been obtained at that time and would be considered very good today. The coal used contained 13,254 B.t.u. per pound of dry coal. The overall plant economy was 1.105 pounds of coal per indicated horse power hour.

Probably the best examples of the latest large pumping station designs in this country are the Fairmount Pumping Station, Cleveland; Western Avenue Pumping Station, Chicago; Missouri River Pumping Station, St. Louis. The Fairmount Pumping Station is completed and has been operated a sufficient time to demonstrate the reliability and economy of some of the latest improvements in power plant equipment for pumping station practice. Both the Chicago and St. Louis Stations are under construction and the duties given are the manufacturer's guarantees of expected duties. The Cleveland Pumping Station differs from the others in that the main pumping units were designed to bleed steam for a central heating system, and may be more corrcctely termed a combined pumping and heating plant; it operates at 300 pounds steam pressure and about 135 degrees superheat. The Chicago Station will operate

at 300 pounds steam pressure and 200° superheat. The St. Louis Station will operate at 300 pounds steam pressure and 245 degrees superheat, or a total steam temperature of about 665°F. This is the highest steam temperature for a pumping station so far designed. Tests made on one of the 75 million gallon per day bleeder units of the Cleveland Station showed a duty when operating without the bleeding feature of 135.5 million foot pounds per million B.t.u.; when operating under the bleeding conditions and allowing for the heat value of the steam bled into the heating system, an overall duty of 198.2 million foot pounds per million B.t.u. was developed. The guaranteed duty of the Chicago Pumping units is 154 million foot pounds per million B.t.u. The guaranteed duty of the St. Louis high duty units is 163.6 million foot pounds per million B.t.u. These three stations embody some of the latest improvements used in central power station design and represent the latest practice in water works pumping station design. No economizers are used in any of the stations, but air preheaters are used in the Cleveland and St. Louis Stations. Stokers are used in all three installations. Steam is bled from the main pumping units for feed water heating.

By comparing the guaranteed duties of the St. Louis steam turbine driven pumping units with the 1908 actual test duties of the California Pumping Station units of the Cincinnati Water Works, it is to be noted that there is a gain in fuel efficiency of only about 7 per cent, which over an eighteen-year period, does not make as good a showing as might have been expected, in view of the gains made in efficiencies in steam generating equipment. However, a comparison of the overall annual charges would show a much greater difference in favor of the present day type of station. If triple expansion pumping engines were used in the St. Louis Station, the initial investment for the complete plant would be approximately $500,000.00 greater than for the steam turbine pumps, and the fixed charges would be approximately $40,000.00 greater per year. Even considering the increased efficiency of the triple expansion pumping units with present day steam practice, namely, 250 pounds pressure, 200°F. superheat, as compared with the steam turbine units with the higher steam conditions, the saving in fuel is only about 8 per cent for the triple expansion unit. The St. Louis officials in tabulating the overall annual charges of the triple expansion unit and the steam turbine unit, found that there was an overall saving under present day conditions of approximately $27,000.00 in favor of the steam

turbine unit. Comparisons made on the Western Avenue Station Chicago equipment under their conditions of operation showed a saving in annual charges of around $67,000.00 in favor of the steam turbine pumping unit.

INCREASING CAPACITIES OF PUMPING STATIONS

With our increasing population and water consumption and the concentration of population in large centers, pumping stations of much greater capacity than those now in use will be required, and engineers must look forward to the future or probable ultimate capacity of the station in selecting the size and type of pumping units. Steam turbines can be built of much greater capacities than present day water works practice require, and therefore there is plenty of margin for the selection of larger equipment for future installations. There are already in use steam turbines of over 100,000 h.p., and the new State Line Generating Station of the Commonwealth Edison Company of Chicago will consist of turbine units of approximately 250,000 h.p. each. The greater the capacity of the turbine, the better the economy, both in fuel and labor charges. Another feature of the steam turbine pumping unit of the latest type is the extreme flatness of the duty curve for variable capacities. On tests made on one of the Cleveland units, there was a change in the duty of less than 7 per cent, with a variation in capacity of two to one. Further improvements will undoubtedly be made along this line, and the future turbine pumping unit will be capable of taking care of a wide variation of output and pressure without appreciably sacrificing efficiency.

Much better economies can be expected in the future in the steam turbine pumping units, if the engineers would specifically set out the requirements of the unit for the particular installation and allow the manufacturers to design it to fit the particular requirements. This calls for special custom machines, but the additional cost will be fully justified. Based on data obtained from manufacturers of steam turbine pumping units table 1 has been compiled showing the expected duties of such equipment in the future, when such units are built for the specific conditions under which they will operate. Such units will probably cost 25 per cent more than the standard commercial machines now being built.

An allowance of about 3 per cent should be made in the above for the auxiliaries. It is fully believed that the above economies will

be realized, as the St. Louis new high service unit guarantees are within 10 per cent of the estimates in the table.

DESIGN OF BOILER PLANT AND AUXILIARIES

With the increasing use of the steam turbine unit, it is essential that the water works engineers consider the design of the boiler plant, auxiliary equipment and selection of plant auxiliaries in a most careful manner in order to obtain the full benefits from the use of high steam pressures and temperatures. The use of the regenerative cycle of operation with the feed water heated by means of steam bled from the main units has been adopted by nearly all large power stations placed in operation in the last five years. It is felt that two-stage bleeding of the main unit will prove the most economical for water works practice. It is not believed that the re-heat cycle will prove economical in water works pumping station practice. In a great many cases the use of both economizers and air preheaters will be fully justified in water works stations, as they have in central power stations. All auxiliaries should be driven by either electric or water motors, or possibly a combination of the two. Steam driven

TABLE 1

Expected duties for different size units operating under different steam conditions

MILLION GALLONS PER DAY (250-FOOT HEAD)	DUTY: MILLION FOOT POUNDS PER 1000 POUNDS STEAM			
	150 pounds pressure dry sat. steam 28-inch vacuum	200 pounds pressure 200° S.H. 29-inch vacuum	300 pounds pressure 300° S.H. 29-inch vacuum	400 pounds pressure 300° S H. 29-inch vacuum
10	130.0	173.7	192.2	194.5
15	143.0	190.4	214.0	219.5
20	150.5	199.0	224.0	230.0
25	154.5	204.0	229.8	236.2
30	156.8	207.0	233.0	240.0
40	160.0	211.0	237.0	245.0
50	162.8	214.5	241.5	249.2
60	165.0	217.5	244.9	252.8
70	167.0	220.0	247.4	256.0
80	168.6	222.2	250.0	258.8
90	170.2	224.3	252.2	261.3
100	171.5	226.4	254.4	264.0

auxiliaries are fast disappearing as they are not necessary, since sufficient steam for feed water heating can be bled from the main units at a more economical rate. Electric driven auxiliaries are preferable, in view of their ease in installation and operation and the elimination of a great deal of small piping, which would be necessary with the water motors. It is believed that the most economical arrangement for auxiliary power would be the installation of a direct current generator on the shaft of the main pumping unit, and operate all auxiliaries of the unit by electric motors driven from this generator. The direct current generator would be operated at the pump speed, and therefore does not involve any special design as the present commercial exciters fit this condition. Furthermore, when it is necessary to vary the speed of the main unit for the changing load conditions, the direct-current generator can be regulated automatically to maintain constant voltage and thus not cause any interference with the operation of any of the auxiliaries. Direct-current motors are preferable for auxiliary drive as variable speeds can be obtained without sacrificing efficiency. The electric driven auxiliaries for each unit should be tied solidly electrically with the generator, without the use of fuses, but with thermal relays for protection. These relays can be set high so that there would be no shutdown of any particular auxiliary, unless it was operating near the danger point. The generators and motors as now manufactured have proven that they are as reliable as any other type of motive power and the combined efficiency of the motor and generator will reach about 83 per cent, which is more efficient than the small water motor, or other forms of auxiliary power. The power for the auxiliaries being generated by the most efficient unit in the plant, namely, the main pumping unit, would naturally show a greater overall economy than if separate small prime movers were used. For starting up the plant a small steam turbo-generator could be used, this would not have to be of high efficiency, as it would be seldom called upon. It would be possible to use storage batteries for emergency purposes or for starting up the plant, but it is believed that this extra expense is not justified in the event a house turbine is used.

INCREASED BOILER RATINGS

As long as stokers of comparatively limited grate area were used there was no necessity of going to boiler furnaces of more than moderate sizes. Furthermore, the natural draft chimney placed a limita-

tion on the boiler output. With the introduction of the economizer requiring the necessity of an induced draft fan to remove the gases from the furnaces, and after it was found that they could be removed as fast as the coal could be burned, power plant engineers began experimenting with the possibilities of operating the boilers at much higher ratings. As the boiler ratings were increased, it was found necessary to increase the furnace volume in order that the gases and particles of coal blown up from the fuel bed would be thoroughly burned before they entered the first pass of the boiler. Coincident with the increase in the furnace volume, it was found that the clinker troubles in the fuel bed decreased. It is not known just how far we can go in increasing the output of boilers, but we do know that the limitations have to do with the clinkering in the fuel bed, formation of slag on the lower tubes and also the maintenance of the brick work. Ventilated boiler walls were at first used and the air passing through the walls was used to burn the fuel. It is now recognized that the water cooled boiler wall offers the best solution. A very late type of boiler, known as the steam generator, has the furnace entirely surrounded by boiler tubes connected directly into the boiler circulation and forming a part of the boiler. There is very little brick work and the maintenance of the furnace walls are thus reduced to a minimum. With this design it is possible to burn a greater amount of coal per cubic foot of furnace volume and develop greater capacities from a given boiler, and a smaller amount of excess air is required for the fuel burning, which, of course, improves the overall boiler efficiency. It is possible also to keep the boiler on the line a greater number of hours per year, which in turn reduces the investment required in reserve boiler capacity. The latest development along this line is the Kip's Bay Station of the New York Steam Company. This boiler will generate 325,000 pounds of steam per hour, with a guaranteed efficiency of 88 per cent. The boiler proper has only 10,672 square feet of heating surface, but the total heating surface of the boiler, economizers, air heaters, furnace walls, etc., is 71,600 square feet. This installation uses pulverized coal.

STEAM PRESSURES AND TEMPERATURES SHOULD NOT GO TOO HIGH

It is not felt that the large pumping station should go to the extremely high steam pressures and temperatures which are becoming the practice in central power stations. In the first place, the pumping station cannot operate in the same manner as the power station,

since it is not possible physically to inter-connect pumping stations and operate some as base-load stations, or at high load factors, as with power plants. Furthermore, the pumping station does not have the extremely wide variations in output that the ordinary central power station has. We do believe, however, that later designs of pumping stations will call for 400 pounds steam pressure, 250° superheat and the use of both air preheaters and economizers with the water cooled furnace walls.

USE OF PULVERIZED FUEL

One of the important contributions to the development of power station design and operation is the pulverized fuel method of firing. Pulverized fuel equipment has been in successful use in a number of the larger central power stations for several years and has thoroughly demonstrated its economy as well as its simplicity. Most of the larger installations, however, have been of the so-called central type, that is, the fuel is prepared in a central plant and distributed to the various boilers. Rapid strides have been made recently in the unit type pulverizer, that is, each boiler has its own pulverizing and preparation plant located directly in front of it, so that the entire preparation and burning equipment forms a part of the boiler unit, and it is believed that the future development of pulverized fuel equipment will be along these lines. Test efficiencies as high as 92.9 per cent were obtained in one installation and an overall boiler room efficiency of 90.4 per cent was obtained for a month's operation. Another interesting achievement of pulverized fuel, was the carrying of a load for five days continuously of 13,000 boiler horse power on one of the River Rouge boilers of the Ford Motor Company, having a heating surface of 26,470 square feet, which is equivalent to approximately 500 per cent rating. Unquestionably the future large water works station will be equipped with pulverized fuel equipment, owing to its ability to carry a high sustained load for long periods of time, its adaptability to varying qualities of fuel, its high efficiency, simplicity and small amount of labor required to operate it. One problem in connection with the use of pulverized fuel that will have to be solved, is the design of some form of dust catcher, particularly for the use of stations located in populated sections. Several types of apparatus for this purpose have been developed, but an entirely satisfactory type has not been developed.

IMPROVEMENTS IN STOKER DESIGN

Coincident with the rapid development of pulverized fuel development has been the improvements in stoker design. Both the chain grate and underfeed stokers have been improved considerably and are available in increased sizes and capable of burning the required amount of fuel for each particular installation. Underfeed stokers are available for operation with air temperatures of 400°F. and for burning as high as 35,000 pounds of coal per hour.

In general, the present day design of the modern large pumping station embodies the following:

Operating conditions: 200 to 300 pounds steam pressure, 200 to 250° superheat, or a maximum total temperature of 675°F.

Pumping units: 40 to 75 m.g.d. turbine driven centrifugal pumps, with standard surface condensers.

Boiler room: 500 to 1000 h.p., 250 to 325 pounds gauge pressure boilers, equipped with 200 to 250° convection type superheaters, air preheaters, stokers or pulverized fuel burning equipment, and forced and induced draft fans. Boilers designed to operate at 200 per cent rating.

Auxiliaries: Steam turbine or water wheel operated or combination of both, or combination of water wheel and electric motor driven equipment, with the exception of air removal pumps, which are of the steam jet type.

Coal and ash handling equipment: Overhead bunkers with suitable belt conveyors from coal storage and traveling weighing larries.

Miscellaneous: Automatic combustion control equipment with central control board, necessary gauges mounted thereon, flow meters and control equipment.

Evaporators, deaerators and two-stage bleeding for feed water heating and the use of the regenerative cycle.

FUTURE PLANT DESIGN

The future plant will probably be designed to embody the following features:

Since the tendency in pumping station design is to follow along the practice of large central power stations, it is believed that the future large pumping station will have pumping units of around 150 m.g.d. capacity. Steam turbines have already been developed for capacities far in excess of any horse power that might be required for operating a pump of this size and it will be up to the pump designers to develop pumps that will meet this requirement. Also the reduction gears will necessarily have to be developed for such large capacities. The future unit will have mounted on the main shaft a direct

current generator capable of driving all plant auxiliaries required for the particular unit, as well as the boiler room auxiliaries operating in connection with each main pumping unit. The boilers will be equipped with air preheaters, economizers, both radiant and convection type superheaters, and the furnaces entirely enclosed with water cooled surfaces forming a part of the boiler circulation. The probable steam pressure will be 400 pounds gauge with 255° superheat, making a total steam temperature of 700°F. The unit type pulverized fuel equipment will be installed in connection with each boiler. Evaporators for makeup water and deaerators will be used for feed water purification, and feed water heating will be done by the use of the regenerative cycle, using two-stage bleeding from the main unit. Emergency power supply for plant auxiliaries or for starting up the plant will be provided by a small house steam turbine, and in addition electrical energy will be supplied from the central power station. The overall duty of the pumping unit will be around 250 million foot pounds per thousand pounds of steam. The overall thermal efficiency of the plant will be approximately 20 per cent.

Electric motor drive for smaller stations

All of the above discussion refers to the very large pumping station, or those serving metropolitan districts. For the medium size pumping station or stations having a capacity of less than 30 million gallons per day, it is believed that the future development will be along the lines of electric motor driven pumping equipment, purchasing energy from the large central stations. Large modern central power stations are rapidly covering the country and these plants are being interconnected so as to enable the individual plant to operate at very high load factors and minimize the investment charges for idle or spare equipment. With the increasing tendency along this line and the attendant reduction in the cost of producing power, it will be more economical to purchase power for pumping service than to attempt to produce it. Furthermore, since the water works service offers a very high load factor to central stations and use can be made of very highly efficient synchronous motors for water works pumps, the day is not very far distant when electric power will be available for water works service for 5 mills per kilowatt hour. The investment in electric motor driven pumping equipment, buildings etc., will approximate from 30 to 40 per cent of that of a highly efficient steam turbine driven station. Therefore, the saving in fixed charges will

be another added advantage in the use of electric power. Attention may also be called to the fact that great improvements in efficiencies have been made in motor driven centrifugal pumping units. Tests on a 70 m.g.d. 170 foot head synchronous motor driven pump installed at Detroit, developed an overall efficiency (pump and motor) of 82.7 per cent and a similar test on a 50 m.g.d. 170 foot head developed an overall efficiency of 84.7 per cent. With power costs of 5 mills per killowatt hour and investment charges of 40 per cent of a steam plant, it can be seen that the overall annual charges of such an installation will make a remarkable showing. It is not uncommon to find overall efficiencies in even small motor driven units of 75 per cent.

Owing to the seasonal variations in water consumption, the average pumping station must make provisions in its equipment to take care of this variation. With centrifugal pumps this can be accomplished by the use of so-called base load pumps with other sizes of additional motor driven pumps to suit the particular requirements so that all pumps will operate at their maximum efficiencies when put into service. Owing to the low investment required by motor driven pumps, this arrangement is entirely feasible and economical.

Motor driven pumps as standbys in larger steam stations

It is furthermore entirely possible in the future that even the large steam turbine driven pumping stations may find it economical to have motor driven centrifugal pumps as standby equipment and to fill in the peak demand as occasion warrants, purchasing the power, rather than have a large amount of idle steam equipment that will be used only a portion of the year. The excess fixed charges on the idle steam equipment would probably be greater than the standby charges required by the power company. Furthermore, greater flexibility in operation could be secured by this arrangement. A further advantage of such an arrangement would be the availability, without an extra charge, of standby power for use by the auxiliaries of the main steam pumping units.

Limited field for Diesel engine

It is believed that the Diesel oil engine pumping unit has a very limited field in water works service, except in possibly small stations where electric power is not available at satisfactory rates. While

the Diesel unit has a very high thermal efficiency, its first cost is considerably in excess of the steam turbine driven unit. This is a reciprocating type of unit and may be compared with the triple expansion pumping unit. Both have very high mechanical and thermal efficiencies, but both are very expensive in first cost and require a much larger investment in building and installation costs than a steam unit. I cannot help but feel that it will have a very limited application, the same as the triple expansion pumping engine.

The electric driven pumping station has a decided advantage in the matter of the selection of a site as the power can be brought to the station regardless of its location, thus allowing the engineer to locate the plant at the most feasible site from a water supply standpoint and reducing the cost of tunnels and expensive underground structures, which would be a charge against the plant requiring them. With the duplicate and loop transmission lines supplied by large central stations inter-connected at different points, there can be no reason why an absolutely uninterrupted power supply cannot be given to the pumping stations, I believe it is only a matter of time until power supply interruptions will be unheard of.

Comparative costs of various drives

We have been called upon to make studies of comparative costs of operating a number of medium size pumping stations with purchased electric power, steam and oil engine drive. With power rates as high as $1\frac{1}{8}$ cents per kilowatt hour; coal costs of $4.00 per ton and oil costs of 5 cents per gallon, we have found in a great many cases that the electric drive is the most economical in overall annual charges. Therefore, with the constant reduction in power rates, it is felt that there will be an increasing use of electric driven equipment for the medium size and small pumping station. At the present time the rates in a great many cases might not justify such a conclusion, but the tendency of electric power rates is downward owing to its increasingly efficient production and transmission. At the same time the trend of prices of other fuels is upward. It would seem, therefore, that the pumping station design in the future will be along two lines, namely, the very large steam turbine driven station, designed along the lines heretofore set forth, and the electrically operated station, with motor driven centrifugal pumps using purchased power.

IODIZATION OF PUBLIC WATER SUPPLIES FOR PREVENTION OF ENDEMIC GOITER[1]

By Robert Olesen[2]

GENERAL CONSIDERATIONS

The theory that endemic goiter is due principally, if not solely, to a relative or absolute deficiency of iodine is now widely accepted. The experimental evidence upon which this conception is based is so convincing and the practical applications are so successful that doubts concerning the tenability of the theory are steadily being dispelled.

Following the convincing demonstrations of Marine and his colleagues in preventing goiter among children and lower animals through the administration of small amounts of iodine, public health officials promptly turned their attention to the important matter of applying this new and effective weapon against a disease of long standing. However, in emulating the examples of these pioneer investigators it became apparent that successful prophylaxis is dependent upon the rigid observance of certain well defined and fundamental principles. These requisites for preventing endemic goiter may be stated as follows:

1. Minute dosage of iodine
2. Palatability of the preparation used
3. Efficiency
4. Harmlessness
5. Low cost
6. Wide range and ease of administration

Goiter prophylaxis versus treatment

There is an unfortunate, as well as rather general, misconception of the distinction between goiter prevention and goiter treatment. To many persons the measures advocated for prophylaxis are re-

[1] Reprinted from Public Health Reports, United States Public Health Service, May 20, 1927, vol. 42, no. 20.

[2] Surgeon, United States Public Health Service, Washington, D. C.

garded as being equally efficacious in the treatment of goiter. This erroneous belief is also entertained by many physicians, their goitrous patients being advised to partake of iodized salt or water in order to obtain relief from thyroid disease. Because of the confusion surrounding the subject, it is believed to be advisable to restate the conditions and expectations of goiter prophylaxis.

Prophylactic doses of iodine are intended solely, of course, for the maintenance of the equilibrium of the normal thyroid. The minute doses of iodine suitable for prophylactic purposes probably have little, if any, effect upon existing thyroid enlargements. If goitrous manifestations are reduced or entirly relieved while prophylactic measures are applied, the results may be regarded as incidental rather than usual.

The treatment of existing goiters is a matter entirely removed from the realm of prophylaxis. Treatment requires, first of all, the services of a physician with special skill and experience, particularly in the diagnosis of the different forms of goiter. Furthermore, the medical attendant must possess a keen appreciation of the poisonous potentialities of iodine. As the usefulness of iodine in treating goiter is definitely limited, the possibilities of causing irreparable damage through the use of this element must be thoroughly realized. Needless to say, the breach between goiter prophylaxis and treatment is a wide one. When the essential differences are more generally understood, both preventive and curative measures will be placed upon a more secure basis.

Water and salt as mediums for conveying iodine

Inasmuch as the form in which iodine is conveyed to those in need of the prophylactic is apparently immaterial, numerous preparations, combinations, and methods have been proposed. However, from a practical standpoint it is essential that the iodine be administered in palatable form to all in need of it and with a minimum of administrative supervision. With these objectives in view, investigators began the search for a medium in which iodine could be conveniently distributed.

Water and salt, being the most frequently used articles of food, were naturally chosen early as suitable vehicles for the general distribution of iodine. Iodized table salt is now extensively used in some sections of the United States and Europe, particularly in Switzerland, Austria, and Italy. While the reports as to its effi-

ciency and harmlessness are not in harmonious agreement, nevertheless iodized table salt may be considered a prophylactic of considerable promise, especially after the iodine content has been scientifically adjusted.

When McClendon and Hathaway announced, in 1924, the apparent existence of an inverse ration between the incidence of endemic goiter and the amount of iodine in the drinking water of a given community, interest in goiter prophylaxis was still further increased. In view of the close relationship presumably existing between goiter and the amount of iodine in water, it was but natural that attention should be directed to the possibility of utilizing artificially treated water in preventing simple goiter.

It appears that Dr. G. W. Goler, health officer, in coöperation with Mr. B. C. Little, superintendent of the waterworks bureau of Rochester, N. Y., were the first to propose, and actually put into effect, the iodization of a public water supply for the prevention of simple goiter. Since that time several cities in the United States and England have instituted the same procedure. In the following discussion will be considered the various angles of the subject.

SPECIAL CONSIDERATIONS

Quantity of iodine required for prophylaxis

Much of the objection which has arisen to the use of iodized water in preventing simple goiter is due to the difficulty in establishing and maintaining a suitable iodine content. Iodine must, of course, be present in sufficient quantity to satisfy the thyroid requirements and, at the same time, be incapable of inflicting damage upon the glands of hypersusceptible individuals. McClendon, after a number of years of intensive research, has concluded that the iodization of water supplies in goitrous sections is an acceptable and efficient means of supplying needed iodine. He believes that 0.01 mgm. of iodine daily is sufficient for physiological requirements and, hence, is prophylactic in character. One-tenth of a pound of sodium iodide per million gallons of water would, in McClendon's opinion, be ample for the maintenance of thyroid equilibrium. Water so treated would contain 1 part of sodium iodide in about 100,000,000 parts of water. McClendon believes that the iodide may be supplied continuously or intermittently, the iodide being proportionately increased when the latter method is followed. By following these

suggestions it is theoretically possible, at least, to have a proportion of 10 parts of sodium iodide to 1,000,000,000 parts of water. McClendon regards a region as amply supplied with iodine when the water contains 5 or more parts of iodine per 1,000,000,000 gallons. This line of demarkation between iodine rich and iodine poor water supplies may, in the absence of an established standard, be used as a point of departure in deciding whether the procedure is justified.

Iodization in Rochester, N. Y.

As iodization of drinking water has been carried out more scientifically in Rochester, N. Y., than elsewhere, the methods adopted in that city are of particular interest. Iodization was begun in Rochester in April, 1923, and has been continued twice a year since that time. The experience gained with the early iodization has resulted in considerable improvement and satisfaction with the later methods. At present there are 21 applications of sodium iodide twice a year, each of 16.6 pounds, the first in May and June, the second during October and November. The applications of sodium iodide are now made as follows: During the first week the salt is added daily. Thereafter the additions are made every other day until 21 have been completed. By this means a concentration of iodine ranging between 14 and 28 parts per billion is insured for a period of nearly five weeks. From the actual analyses of the water it is estimated that each person in Rochester ingests 3.1 mgm. of iodine in one year. This amount coincides rather closely with the annual quantity of iodine, 3.65 mgm., recommended by McClendon.

In calculating the quantity of iodine present in water after treatment with an iodide it is necessary to remember that the element iodine is only a portion of the compound ordinarily used. Thus, the percentage of iodine in sodium iodide is approximately 85 per cent. Therefore, in estimating the parts per billion of iodine present in water, the calculations, in the instance of sodium iodide, must be made upon the basis of percentage composition.

Per capita water consumption and iodine dosage

In the absence of accurate knowledge as to the average per capita consumption of water, it is obvious that the amount of iodine ingested from an iodized supply is uncertain. Ordinarily, it is estimated that 2 quarts of liquid are consumed each day by the average person, one-

half of this amount being water, while the remainder is fluid in coffee, tea, and other beverages. Probably an additional quart of liquid per capita is used in cooking, thereby affording another source of iodide.

If each person in need of prophylaxis consumed definite quantities of iodized water and the amount of iodide was sufficient to insure results, this method of supplying the needed element could be relied upon to achieve results. Unfortunately, the consumption of water varies within a wide range, some individuals drinking considerable water while others use relatively small quantities. However, the amount of iodine present in properly treated water is so minute that no harm could possibly result from an excessive consumption of water. On the other hand, it is conceivable that these same minute doses of iodine will prevent simple enlargement of the thyroid gland. At the same time, it must be conceded that the iodine obtained from treated water is likely to be uncertain in quantity.

Objections to the use of iodized water

The objections raised against the use of iodized drinking water as a means of preventing endemic goiter have been numerous. The strongest disapproval has come from the group which discredits all attempts of scientific medicine to minimize the prevalance of disease. Iodization of drinking water is termed by them a "doping" or poisoning process. In view of the minute quantities of iodide used, and the scientific premise on which the procedure is based, the objections of an organized minority may be somewhat discounted. There are, however, certain apparently legitimate objections which deserve consideration. Among these may be mentioned the possibility of inaugurating toxicity in apparently benign goiters, excessive cost, waste, offensive taste, undesirable chemical combinations and the like. Each of these objections may be considered separately.

Cost of iodizing public water supplies

The cost of a public health measure is an item of obvious concern to administrators and tax-payers. It is manifest that goiter prevention should be alloted a fair proportion of public funds commensurate with its relative importance. Heretofore, estimates of the cost of iodizing public water supplies have varied within wide limits. However, the actual expenditures incurred by the city of Rochester for this purpose apparently form a reasonable point of departure for other

calculations. Rochester spends approximately $3000 a year in iodizing its water. As the city has a population of 300,000, the annual per capita cost of the procedure is 1 cent. The sodium iodide used for treating the water costs about $4.30 a pound, delivered in Rochester.

Anaconda, Mont., is another city in which iodization of the public water supply is being practised. The annual expenditure for sodium iodide in this city is $600, or approximately $0.05 per capita, the sodium iodide costing $4.75 per pound f.o.b.

Kimball estimates that it would cost the city of Cleveland $125,000 a year to iodize the drinking water. The health officials of Chicago

TABLE 1

Estimated cost of iodization of public water supplies in 4 cities in the United States

City	Population, 1920	Average pumpage per day	Amount NaI per day	Cost NaI per pound	Cost per year, 3 weeks' dosage twice a year	NaI in the water	Cost per capita year (approximate)
		m. g.	*pounds*			*p.p.b.*	*cents*
Rochester, N. Y.	295,750	25	16.6	$4.35	$3,032.82	75	1.0
Sault Ste. Marie, Mich.	12,096	3	2	4.35	365.40	75	3.0
Cleveland, Ohio	796,841	150	100	4.35	12,180* 18,270†	75	1.5 2.3
Cincinnati, Ohio	401,247	56	37	4.35	4,506.60* 6,759.90†	75	1.1 1.6

* Two weeks.

† Three weeks.

estimate that $57,120 a year would be required to increase the iodine content of Lake Michigan water to one-seventy-fifth grain per gallon. With sodium iodide costing $3.75 a pound, delivered, Mellen estimated that the water supply of Minneapolis, Minn., could be iodized at a total annual cost of $6500, or a cent and a half per person. The cost in Duluth, Minn., would be less than $2000 a year.

Bolt and Wolman have prepared an informative summary of costs, shown in table 1, based upon the expenditures in Rochester, N. Y., and Sault Ste. Marie, Mich., and the estimates of Ellms for Cleveland and of Bahlman for Cincinnati.

The costs in this table are based upon the assumption that the quantities of sodium iodide used will be sufficient to secure a content of 75 parts of iodine per billion gallons of water.[3] However, in all probability a greater amount of sodium iodide, and consequently larger expenditures, would be required to secure this concentration. Most of the estimates which have been given indicate that the expense attached to iodization of public water supplies is reasonable, provided, of course, favorable results are forthcoming.

Waste

To many persons the iodization of a public water supply appears to be a wasteful, and consequently an unnecessarily costly, method of conveying iodine to those in need of it. Inasmuch as less than 0.5 per cent of a water supply is used for drinking and cooking purposes, there would seem to be justification for the charge that most of the water is unnecessarily iodized. Obviously, nearly all of any water supply is used for sanitary purposes, laundering, boilers, street flushing, automobile washing, and numerous other purposes unassociated with disease prevention.

However, the same objections may reasonably be raised with regard to other methods of water improvement. The safeguarding of water supplies by filtration and chemical treatment is so well established as to be accepted as a necessity rather than an esthetic refinement or luxury. Thus, raw water supplies are subjected to coagulation, sedimentation, filtration, and disinfection, all expensive processes, in order that the fluid may be made safe for human consumption. Lime, alum, and chlorine are widely used in connection with such water treatment. For softening hard water, lime and soda are frequently employed, while copper sulphate is used as an algicidal

[3] It will be noted that there is a marked difference between the 5 parts of iodine per billion gallons of water regarded as sufficient by McClendon and the 75 parts per billion gallons upon which the cost data presented here are calculated. These estimates were, of course, made by different observers. Obviously, the proper amount of iodine to be conveyed in drinking water for prophylactic purposes is not definitely known. If, as McClendon contends, 5 parts of iodine per billion gallons of water is adequate, the cost of iodizing drinking water would be materially less than the amounts given in the table. It may also be pointed out that the Rochester experiment shows that the amount of iodine recoverable from water after the addition of sodium iodide is much less than the quantity added.

agent. None of the water supplies treated with the chemicals just mentioned are now regarded as drugged, medicated, or doped. Quite on the contrary, the processes are generally conceded to be necessary for the safeguarding of comfort and health, even though only a comparatively small quantity of the water is actually consumed. Moreover, present day opposition to the chemical treatment of polluted or unsuitable raw waters is insignificant, permitting the steady extension of protective measures, with consequent lessening of water-borne diseases.

Reaction between iodine and chlorine

In discussing the iodization of water before the Ohio Conference on Water Purification in 1924, Ellms intimated that an undesirable chemical reaction occurred between the iodine and the chlorine, so commonly used for disinfection. Although his observation lacks confirmation, Ellms contended that chlorine has a tendency to decompose sodium iodide and liberate iodine. While the element would not be lost, its combination with organic matter, or reaction with other normal constituents, might adversely affect its prophylactic value. No objection of similar character has been noted in the literature.

Taste

Much greater quantities of iodine than those ordinarily recommended could be placed in drinking water without imparting a detectable taste. Mellen, for example, states that he has drunk water containing one thousand times the amount of iodide proposed for Minneapolis (10 parts per billion), without being able to detect the taste. It is known, too, that individuals going from a district having water with a low iodine content to another locality with a high iodine content do not complain of an offensive taste. Moreover, there is no record of damage having been inflicted upon the thyroid by reason of removal from a district with low iodine content to one with a high content.

Hyperthroidism

The possibility of stimulating an apparently quiescent thyroid gland to hyperactivity and toxicity through the use of iodine is a contingency particularly to be guarded against while employing prophylactic measures. However, it is difficult to understand how the minute quantities of iodine available in iodized drinking water

could exert such a detrimental effect. It would seem more reasonable to question the ability of the measure to exert any beneficial influence upon the normal thyroid gland. However, as there is convincing evidence that minute doses of iodine, in other combinations, aid in maintaining the thyroid equilibrium, it is likely that iodized water will, under fair conditions, do likewise.

No instances of hyperthyroidism following the use of iodized drinking water appear to have been recorded. The opinion of Dr. C. H. Mayo, concerning the harmlessness of iodized water, is typical of many expressions from physicians who have considered the matter. Dr. Mayo has said, in a communication addressed to the health commissioner of Minneapolis, "As there is no type of goiter which would be injured by the small amount of iodine obtained from the water, I do not believe there would be any risk whatever in such cases."

On the other hand it can not be denied that some physicians are apprehensive lest the "promiscuous distribution of iodine," as they term it, to those not in need of the element, caused a marked increase in hyperthyroidism. Manifestly, there is need for accurate information on this point.

PRACTICAL APPLICATIONS AND RESULTS

Cities using iodized water

So far as can be learned from correspondence with all of the State, county, and city health officers (the last named in cities having populations in excess of 10,000) in the United States there are only two places in which iodization of drinking water is now practiced, Rochester, N. Y., and Anaconda, Mont. Iodization of the Rochester water supply began in April 24, 1923, and will be continued according to an announcement in the Rochester health bulletin of May, 1926, "until, through education or in some other way, we get the people to consume iodized salt."

Iodization of the Anaconda, Mont., water supply began in April, 1925, and was continued in October, 1925, April, 1926, and October, 1926. Children in the Anaconda schools are also receiving 10 mgm. chocolate-iodine tablets once a week for 30 weeks during the school year. Iodization was practiced for a short time in Sault Ste. Marie, Mich. and Virginia, Minn., but was speedily abandoned because of numerous objections from residents.

The health and water works officials of Minneapolis, Minn., have

repeatedly advocated iodization of the public water supply. Moreover, preparations were made to put the procedure into effect. Owing, however, to many objections the project never materialized. In Duluth, Minn., the water and light department of the division of public utilities, has been very active in advocating iodization of the water. According to the investigations made by McClendon, the Duluth water contains the least amount of iodine of any locality in the United States. However, objections have prevented the inauguration of the measure.

In the county of Derbyshire, England, iodization of drinking water was practiced on a limited scale during 1925, the results being reported by the school medical officer. According to J. A. Goodfellow, the water supplies of Ilkeston and Heanor are being treated with sodium iodide. In these last-named places the iodization is continuous, 2 pounds of sodium iodide being added weekly.

Method of adding iodide to water

Owing to the readiness with which sodium and potassium iodide dissolve in water, no difficulty has attended the introduction of these salts in large public supplies. In Rochester the weighed amount of sodium iodide is placed in a bag and allowed to dissolve in the swiftly running water entering Rush Reservoir from Hemlock Lake. That the salt is disseminated throughout the reservoir is attested by the uniform iodine content of water from widely separated city taps. Apparently no special apparatus or means for insuring even distribution of iodine in a water supply are required.

Alleged collateral benefits of iodized water

Quite aside from the beneficent influence presumably exerted upon the normal thyroid gland through the use of iodized water, may be mentioned the advantages of possibly occurring in other directions. In extolling the cause of iodized water, the Water and Light Department of Duluth, Minn., makes the following statement (Bulletin 43, issued in April, 1926):

> Everyone drinks water every day, uses it to water his garden, sprinkle his lawn, lay the dust in the street in front of his house, washes his floors, his clothes, his face and hands, and even bathes in it. If iodized and used on the garden it gives the vegetables and fruits their proper proportion of iodine. Some of it is evaporated into the air where it combats dust carriers of infection. Iodized water for the dairy herds helps to iodize the milk. It is beneficial, even

if breathed into the lungs. However, most of it is washed into the sewers, where it is carried out into the lake, where it prevents goiter in our food fishes. None of the iodine is actually wasted or lost.

Whether, with our present incomplete knowledge of the subject, this enthusiastic view is justified, can only be conjectured.

Results

The chief difficulty in appraising the efficiency of iodized water as a goiter prophylactic arises from lack of clear-cut statistical evidence. In most communities in which goiter is present to an extent sufficient to warrant the institution of prophylactic measures, iodine is available in several forms. In addition to iodized salt, iodine of some other form may be prescribed by the family physician. When the drinking water is also iodized, it is, of course, difficult to decide which of the several measures deserves credit for changes in goiter incidence.

According to the health authorities in Anaconda, Mont., endemic goiter is less prevalent than before prophylaxis was inaugurated. However no accurate figures supporting this impression appear to be available. Owing to the fact that both iodized water and iodine tablets are being used by the school children, it is impossible to ascribe the lessened incidence definitely to either of the two methods.

The health authorities of Rochester, N. Y., claim a reduction in goiter incidence following the iodization of the public water supply. In 1923 there were 3844 children with visible thyroid enlargements; in 1924, there were 1766; and in 1925, 2010. While there has apparently been a decrease in the number of instances of goiter observed, the testimony would be more convincing if percentages based upon the total annual numbers of children of each sex examined were available. Inasmuch as the use of iodized table salt has been recommended in Rochester, it is questionable whether any reduction in goiter incidence may be ascribed solely to the iodization of drinking water.

Derbyshire, England

According to Ash, goiter increased among the boys and girls of four schools in Derbyshire County, England, following iodine prophylaxis. The experiments lasted approximately ten months each, and included the use of iodized water alone, iodized tablets alone, and combinations of the two measures. In each instance Ash recorded a decided in-

crease in the amount of goiter at the second examination. The results of the Derbyshire experiments have been arranged in tabular form in table 2.

An increase in the prevalence of goiter among children following the use of iodine is most unusual and no similar incident has been recorded in the United States. As the numbers of children included in the experiments were small, and no parallel control groups were studied, the validity of the conclusions may be questioned. Iodized water alone was used in only one of the four experiments.

TABLE 2

The effects of one year's use of iodized drinking water and iodized tablets upon the thyroids of the pupils in four schools in the county of Derbyshire, England

School	Time of examination, 1925	Iodine supplied in—	Ages	Sex	Number examined	Number of goiters	Per cent of goiters
1	February 26	Tablets and water	9–14	Female	306	75	24.5
	December 10				287	192	66.9
2	February 27	Water only	5–10	Female	108	32	29.6
	December 11				118	50	42.3
	February 27		5–7	Male	59	11	18.6
	December 11				50	13	26.0
3	February	Tablets only during first half year	7–14	Female	271	127	46.8
	January, 1926	Water only during second half year			283	146	51.5
4	March	Tablets only during second half of year.	10–18	Female	151	62	41.3
	December				131	85	64.8

The results of the experiments in which both iodized water and iodized tablets, or iodized sweets, as Ash calls them, were used, are an indictment of iodine prophylaxis rather than the methods employed. It is felt that the time during which the experiments were carried on was too short to permit of an accurate appraisal of either of the methods employed. It would be interesting to learn something of the status of the several groups one year after the complete withdrawal of iodine.

Opinions of health officers concerning iodized water

The proposal that endemic goiter be prevented through the medium of drinking water has created widespread interest. Health officers, especially, have manifested marked interest in the possibilities of the measure. In an effort to learn the attitude of county and city health officers toward iodized water, a questionnaire was addressed to 1040 workers of this type in the United States. The replies, received from 56.3 per cent of this group indicate an uncertainty concerning both the justifiability and efficiency of treating drinking water with iodine. The answers received from 566 health officers may be tabulated as follows:

Favorable to use of iodized water	159, or 28 per cent
Undecided	105, or 18.5 per cent
No opinion	202, or 35.7 per cent
Opposed to measure	100, or 17.7 per cent
Total	566

CONCLUSIONS

The iodization of public water supplies, in its present state of development, can not be recommended for widespread adoption. However, the measure appears to be theoretically sound and promising as a means of reducing goiter incidence when correctly used. The chief points in its favor are its comparatively low per capita cost, its apparent harmlessness even to existing goiters, and its wide range of applicability.

So far, there is considerable doubt as to the ability of iodized water to reduce the incidence of endemic goiter. This important point should be clearly established before further commendation of the measure can be forthcoming. However, the lack of convincing evidence of the efficiency of iodized water appears to be the result of poorly controlled experimental applications, rather than of any inherent defect of the procedure itself.

While the measure can not be recommended for wider use until stronger evidence concerning its value is forthcoming, nevertheless, iodized water should not be condemned as worthless. Rather there is need for more precise experimental work, with careful and repeated thyroid examinations, both of children as well as adults. Comprehensive control experiments in nearby communities, among groups which are not consuming iodized water, are also essential. In con-

junction with these precautions, it is also desirable that epidemiological observations be made for the purpose of learning whether other iodine preparations are being used. The results of such scientifically performed experiments would readily disclose the worth or worthlessness of iodized drinking water as a means of preventing simple goiter.

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PROPOSED UNITED STATES GOVERNMENT SPECIFICATION FOR CENTRIFUGALLY-CAST IRON PIPE[1]

By H. A. Stacy[2] and I. J. Fairchild[3]

A survey of recent Federal installations having indicated the growing importance and acceptability of cast iron pipe made by centrifugal processes, the Pipe Committee of the Federal Specifications Board decided to attempt the preparation of specifications for this material. The specification, when adopted by the Federal Specications Board, will become the official purchase standard for all activities of the United States Government.

Other reasons leading to the decision were (1) the greater strength of centrifugal pipe compared with vertical sand cast pipe, (2) greater homogeneity, (3) smoother interior, (4) lighter weight, and (5) lower cost when laid. Furthermore, conditions in the industry indicate that centrifugally cast pipe may possibly supplant other pipe in the small sizes due to a faster rate of production with fewer men, (one DeLavaud machine with 5 men will produce 30 to 40 lengths of 6-inch pipe per hour) and better working conditions which reduce the uncertainty of the skilled labor problem.

In the United States, mass production of centrifugal pipe is confined to two general methods, (1) the DeLavaud process (used by the United States CastIron Pipe and Foundry Company at their Burlington, N. J., and Birmingham, Ala., plants, and by the National Cast Iron Pipe Company, which employs a revolving, water-cooled, metal mold), and (2) the "Mono-cast" or "Sand Spun" method (used by the American Cast Iron Pipe and Foundry Company and R. D. Wood and Company), in which the revolving metal flask is lined with skin-dried, green sand. No cores are required in either process except for the bells.

[1] Published by permission of the Chief Coördinator, Bureau of the Budget, Washington, D. C.

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The preliminary study revealed a number of obstacles in the way of purchasing this pipe on a competitive basis. First, the pressure classes or ratings are different, the DeLavaud pipe (4- to 12-inch size) being made for working pressures of 50, 150 and 250 pounds per square inch while the Mono-cast or Sand Spun pipe is made for 100, 150, and 250 pounds per square inch; second, thicknesses for the same working pressures seem to bear no relation to each other; third, the thicknesses now used in either process bear no logical relation to any of the accepted formulas for cast iron pipe; fourth, the lengths are inconsistent, 12 feet being used in the DeLavaud process while 16 feet lengths are regular for Mono-cast and 16 feet 4.85 inches (5m) lengths for Sand Spun; fifth, the former omits the bead on spigot end for all sizes and classes in contrast to the latter which retains the bead: sixth, there is a discrepancy in outside diameters for sizes above 12 inches; and seventh, dimensions of the bells are different.

Such differences would seem irreconcilable; however, it is believed each obstacle has been surmounted in a manner acceptable to both producer and consumer. The practical limitations of tolerance in manufacture, considerations involving predominating values of pressure and standard pressure ratings for small iron pipe fittings, led to the empirical adoption of 150 and 250 pounds per square inch as preferable working pressure ratings.

To provide a basis for selection of thickness dimensions, the Brackett, Fanning and other formulas were studied, and many papers citing the experience of water departments were digested. In general, experience with regular sand cast pipe indicates that the present thicknesses are more than adequate for the smaller sizes and are not entirely dependable for the larger sizes. The Brackett formula which seems to be most favored at present and which provides for a gradual reduction in allowance for water hammer with increase in diameter appeared to be most nearly logical, except for the second term. Therefore a new formula was worked out, which for convenience we will call the Fairchild formula, as follows:

$$t = \frac{fd\,(P + P^1)}{2S} + \frac{0.30}{d^{0.3}}$$

in which t = thickness in inches

f = factor of safety (4 for centrifugal pipe)

d = nominal interior diameter, inches

S = ultimate stress, lbs. per sq. in.

P = working pressure, lbs. per sq. in.
P^1 = pressure due to water hammer as follows:

DIAMETER	P^1
inches	
4–10	120
12	110

Ultimate stresses in tension test specimens of DeLavaud pipe have been reported well above 40,000 pounds per square inch. However, stresses computed from actual bursting pressures indicate that the bursting strength may fall as low as 15,000 pounds per square inch, due, no doubt, to the fact that hydrostatic tests search out the thinnest spots or the weakest portions of the pipe. We have therefore selected 20,000 pounds per square inch as a safe ultimate stress and have used a factor of safety of 4 instead of the usual 5 as a concession to the homogeneity and general structure of the metal. The formula thus reduces to $t = \frac{d(P + P^1)}{10,000} + \frac{0.3}{d^{0.3}}$.

The second term of the formula provides an additive correction value of from 0.2 inch for 4-inch pipe to 0.08 inch for 72-inch pipe to allow for eccentricity, handling, corrosion, etc. Since centrifugally cast pipe is more uniform in thickness and is not particularly subject to eccentricity, it follows that the corrective term should be less than for other pipe. The form of the second term was chosen to provide a logical correction for all sizes including those beyond the present range of production. The second term of the Fanning formula passes through zero when d = 100 inches; in the Fairchild formula the second term changes more and more slowly as the diameter is increased until at 72 inches diameter it becomes nearly constant. This formula therefore provides a relatively greater correction value for the larger sizes of pipe without unduly penalizing the smaller sizes. Though slightly more difficult to handle, when once computed for the series of diameters the solution of this term need never be repeated. Values of the second term for the usual diameters are given in table 1 and are shown graphically in figure 1.

Having in mind the uncertainties of formulas for computing flow of water in pipes which inhibit an accuracy closer than 10 per cent under known conditions of pressure and the wide variations in pressure common to average pipe lines in service, it seems entirely unnecessary to

hold the inside diameter to a constant value for the different classes in the same nominal size.

It is proposed to make the outside diameters identical with Class A of A. W. W. A. for all classes in diameters to and including 12 inches. It will be seen from table 2 that the resulting maximum deviation of inside diameter from nominal size is 0.28 inch in the case of 12-inch 150-pound pipe.

For the sizes to and including 12-inch, centrifugally cast pipe will intermember with A. W. W. A. Classes A, B, C, or D, already in the ground, except that some selection may be required in the larger sizes to avoid conflicting extremes of tolerance. This system will, of

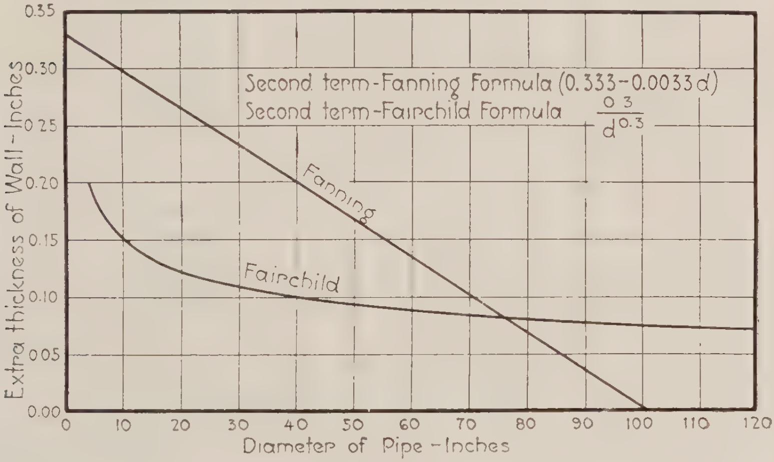

FIG. 1

course, provide complete intermembering of both classes of centrifugally cast pipe in the sizes covered.

In preparing tables from the computed thicknesses, slight deviations, not exceeding 0.01 inch in general, have been made to provide more nearly uniform increments of thickness from one size to the next. In order to provide a sufficient thickness of metal for satisfactory tapping for service lines, the thicknesses have been increased slightly over that computed by the formula for 4 inch pipe in both classes and for 6 inch in the 150 lb. class.

There seemed to be no objection to the acceptance of 12-foot, 16-foot or 5-meter lengths provided the bidder states which length he

proposes to furnish to permit proper allowances for number of joints and other laying conditions involved.

TABLE 1

NOMINAL DIAMETER OF PIPE	VALUE OF $\frac{0.30}{d^{0.3}}$
inches	
4	0.198
6	0.175
8	0.161
10	0.150
12	0.142
14	0.136
16	0.131
18	0.126
20	0.122
24	0.116
30	0.108
36	0.102
42	0.098
48	0.094
54	0.091
60	0.088
72	0.083

TABLE 2

NOMINAL DIAMETER	INSIDE DIAMETER					
	A. W. W. A.				Proposed F. S. B.	
	Class A	Class B	Class C	Class D	150 pounds	250 pounds
inches	*inches*	*inches*	*inches*	*inches*	*inches*	*inches*
4	3.96	4.10	4.04	3.96	4.18	4.10
6	6.02	6.14	6.08	6.00	6.22	6.10
8	8.13	8.03	8.18	8.10	8.29	8.03
10	10.10	9.96	10.16	10.04	10.26	10.06
12	12.12	11.96	12.14	12.00	12.28	12.04

Regarding the omission of bead on the spigot end, it is believed that pipe lines without beads which will stand proof pressures in the open trench, should give no trouble from this source when covered.

The test bar cast separately has been omitted since in centrifugally cast pipe it is necessary to make such tests as may be required on specimens cut from the pipe itself. Test strips cut from the pipe are tested for hardness, moduli of elasticity and rupture, and chemical analyses are made to determine total phosphorous and sulphur.

To provide information looking toward future improvement in the specification and in the product, manufacturers are required to furnish data as to pouring temperatures and analyses showing total carbon, manganese and silicon.

Comment or constructive suggestions applicable to the specification will be appreciated and should be addressed to I. J. Fairchild, Chairman, Pipe, Fittings, Valves, etc., Committee, Federal Specifications Board, Bureau of Standards, Washington, D. C.

TABLE 3

Standard dimensions and weights

Nominal inside diameter, inches	Actual outside diameter, inches	Dimensions of bells inside: Diameter, inches	Dimensions of bells inside: Depth, inches	Class I—150 pounds pressure, 346 feet head: Thickness, inches	Class I: Weight, pounds: 12 feet long	Class I: Weight, pounds: 16 feet long	Class I: Weight, pounds: 16 feet 4.85 inches long	Class II—250 pounds pressure, 576 feet head: Thickness, inches	Class II: Weight, pounds: 12 feet long	Class II: Weight, pounds: 16 feet long	Class II: Weight, pounds: 16 feet 4.85 inches long
4	4.80	5.60	3.50	0.34	201	260	269	0.37	215	280	289
6	6.90	7.70	3.50	0.36	312	402	412	0.40	340	442	453
8	9.05	9.85	4.00	0.38	437	566	580	0.46	514	669	685
10	11.10	11.90	4.00	0.42	586	763	780	0.52	706	922	944
12	13.20	14.00	4.00	0.46	763	993	1,017	0.58	935	1,222	1,252

The text of the specification, dated July 15, 1927, follows:

UNITED STATES GOVERNMENT PROPOSED MASTER SPECIFICATION FOR PIPE, WATER, CENTRIFUGALLY-CAST IRON

I. GENERAL SPECIFICATIONS

The applicable technical and inspection requirements of United States Government General Specifications for Metals, Federal Specifications Board Specification No. 339, are incorporated herein.

II. TYPE, SIZES, CLASSES

1. Pipe shall be furnished in bell and spigot type, with or without bead unless otherwise specified, with lead groove in bell, and in the following classes:

Class I. 150 pound pressure
Class II. 250 pound pressure

2. This specification covers sizes 4 to 12 inches inclusive.

3. Pipe shall be furnished coated, unless cement lined or uncoated pipe is required in the purchase order.

III. MATERIAL AND WORKMANSHIP

All pipe shall be made of cast iron of good quality, and of such character as shall make the pipe strong, tough and of even grain, and soft enough to satisfactorily admit of drilling and cutting. Each pipe shall be smooth, free from cold shuts, scale, lumps, blisters, sand holes and defects of every nature which unfit it for the use intended. It shall be straight, and shall be true circles in section with its inner and outer surfaces concentric. No plugging, filling, or burning in will be allowed.

IV. GENERAL REQUIREMENTS

1. Casting. All pipe shall be cast centrifugally in machines. A record of the melting and pouring temperatures of the iron shall be furnished the inspector, when requested.

2. Chemical analysis shall be made by the manufacturer from each heat to determine graphitic and combined carbon or total carbon, if the separate determinations are not available, manganese, phosphorus, sulphur and silicon, and duplicate copies of test reports shall be furnished the inspector. Sulphur shall not exceed 0.10 per cent and phosphorus 0.90 per cent in either ladle or inspection analysis.

3. Annealing. Pipe cast in metal contact molds, after withdrawing from machines, shall be annealed to meet the hardness limits designated under "Inspection and Tests." Pipe cast in sand lined molds, and stripped while showing color of heat, shall be placed in an oven, and shall not be removed therefrom until cooled to 500°F. or under.

4. Lengths. Pipe shall have a laying length of 12 feet, 16 feet or 16 feet 4.85 inches (5 meters). Not more than 10 per cent of cut pipe shall be accepted. Such cut pipe shall be no more than one foot under nominal laying length. Bidder shall state which length he proposes to furnish.

5. Tolerances in diameter. The inside diameters of the bells and the outside diameters of the spigot ends of pipe, exclusive of bead, shall not vary plus or minus from the tabulated dimensions by more than 0.06 inch for pipe 12 inches and less in nominal diameter.

6. Tolerances in thickness. The tolerances in thickness, plus or minus, hall not exceed those listed below.

NOMINAL DIAMETER	TOLERANCE, PLUS OR MINUS
inches	*inches*
4	0.04
6	0.045
8	0.05
10	0.055
12	0.06

For all sizes of pipe, tolerances not exceeding 0.02 inch additional to above will be allowed for spaces not exceeding 8 inches in length in any direction.

7. Tolerance in weight. The weight of no single pipe shall be less than the nominal weight by more than 5 per cent.

8. Cleaning. All pipe shall be thoroughly cleaned, and any rough spots in bells or on spigot ends shall be ground, before coating or lining.

9. Physical requirements. Pipe shall conform to physical requirements as given in Section VI–5, 6 and 7.

10. Coating. Unless otherwise specified all pipe shall be completely coated inside and out with coal-tar pitch varnish, to which sufficient oil shall be added to make a smooth coating, tough and tenacious when cold, not "tacky" and not brittle.

11. Cement mortar lining. (*a*) When required in the contract or purchase order, pipe shall be lined with cement mortar. No coating will be applied to the outside unless specifically provided in the contract or order. Cement shall be standard Portland, complying in all respects with the requirements of United States Government Master Specification No. 1 for Portland Cement in effect on date of invitation for bids. Sand shall be clean, free from organic matter, loam, and other foreign material. It shall be screened through a screen with not less than 12 meshes per inch.

(*b*) Unless otherwise specified mortar shall be approximately three parts of cement to one part of sand by volume, and thoroughly mixed in a power mixer, using only sufficient water to permit of proper distribution of mixture in pipes. Mortar shall be promptly used after mixing and no mortar shall be used which has attained its initial set.

(*c*) Cement mortar lining shall be smooth, continuous, completely adherent and reasonably free from check cracking. All excess mortar shall be removed from the bottom of the bell. No pipe shall be shipped until lining is thoroughly hard.

(*d*) Thickness of linings shall be $\frac{1}{8}$ inch $\pm \frac{1}{16}$ inch for all sizes to and including 12 inch.

12. Weighing. Each length ofpipe shall be weighed and the weight plainly marked on the pipe. Coated pipe shall be weighed after coating. Cement lined pipe shall be weighed before lining and the mark shall be placed on the outside surface.

13. Handling. Care shall be taken in handling the pipes not to injure the coating, and no pipes or other material shall be placed in the pipes during transportation, or at any time after they have been coated.

14. In addition to the weight being painted on the pipe as previously specified, each pipe shall have distinctly cast or stamped into the metal on the face or outside surface of the bell the manufacturer's mark, and the year in which the pipe was cast. When so specified in the invitation for bids each pipe shall also have cast upon it or stamped into the metal a designated symbol.

V. DETAIL REQUIREMENTS

The pipe shall accurately conform to the dimensions given in table 3.

VI. INSPECTION AND TESTS

1. The contractor shall furnish the inspector, free of cost, such facilities as may be necessary for the performance of his work.

2. The inspector shall have free access at all times to all parts of any manufacturing plant which concern the manufacture of the material ordered.

3. All handling of material, sampling, preparation of test specimens, and testing thereof, except purchaser's chemical analysis, shall be performed or furnished by the contractor without expense to the Government. Where the manufacturer has no facilities for making tests or analyses required, they will be made at some suitable place in the vicinity, at the contractor's expense, and in the presence of the inspector.

4. All pipe shall be subjected to a careful surface inspection, and hammer and rolling tests. All bells shall be tested by circular gages and no pipe will be accepted which is deficient in joint room.

5. Tests of material. From each 300 lengths of pipe, or fraction thereof, of each size in the contract or order, one length of pipe shall be selected by the inspector before coating. From each sample pipe there shall be cut and machined one test strip 12 inches long, 0.50 inch deep, and the full thickness of the shell in width. This shall be tested as a beam (with machined surfaces top and bottom) on supports 10 inches apart with load applied at two points $3\frac{1}{3}$ inches from the supports. The strip shall be accurately calipered at point of rupture and stress calculated by the formula

$$S = \frac{Plc}{6I}$$

The secant modulus of elasticity at the breaking load, shall be calculated by the formula

$$E = \frac{23Pl^3}{1296Iy}$$

In these formulas S = modulus of rupture
E = modulus of elasticity
P = total load
l = length of span
c = distance to extreme fibre
I = moment of inertia
y = center deflection at load P

The secant modulus of elasticity shall not exceed 15,000,000 pounds per square inch with a corresponding modulus of rupture not less than 40,000 pounds per square inch or as an alternate, the secant modulus of elasticity shall not exceed 10,000,000 pounds per square inch with a corresponding modulus of rupture not less than 35,000 pounds per square inch.

6. Hydrostatic tests. Each length of pipe shall be subjected to a proof of 500 pounds hydrostatic pressure, and while under pressure shall be subjected to a hammer test. A pressure gage shall be used to show the pressure applied, and the pipe shall be under test pressure at least one-half minute. Any pipes showing defects by leaking, sweating, or otherwise, shall be rejected.

7. Rockwell tests. Upon the machined edges of each test strip there shall be made at well distributed points not less than 3 determinations, using a 1.59 mm. ($\frac{1}{16}$ inch) ball and 100 kgm. load. The average Rockwell No. shall not exceed 95. An additional determination shall also be made for pipe cast in metal contact machines, upon the outside of each pipe, using a portable type machine. The equivalent Rockwell No. for the exterior shall not exceed 95.

8. Chemical analyses. In addition to such analyses as are required to be made by the contractor, the inspector may obtain samples for chemical analysis from finished material representing each melt. The inspector may have samples for chemical analysis taken from test strips, or from any part or parts of the material concerned, provided the serviceability of the part or parts is not destroyed. The sample taken for chemical analysis shall be of sufficient size to permit five analyses to be made.

9. Rehearing. In case of dissatisfaction with results of the chemical analysis, the contractor may make claim for a rehearing, in which case the chemical composition shall be determined by a Government laboratory. Part of any sample taken for chemical analysis shall be furnished the contractor if he so requests the inspector at the time the sample is taken.

10. Retests. If any test specimen shows defective machining or obvious lack of continuity of metal it may be discarded and replaced by another specimen selected by the inspector. If any of the test specimens selected fails to meet the requirements specified and the purchaser permits a retest, at least two additional replacement specimens shall be selected by the inspector, both of which shall meet requirements.

VII. MARKING OF SHIPMENTS

Marking of shipments shall be in accordance with best commercial practice unless otherwise specified.

VIII. NOTES

1. Invitations for bids should state the number of linear feet of pipe desired and payment should be made on a per foot basis. No bids should be accepted on a tonnage basis.

2. If special symbol is desired (see Section IV-14) it shall be so stated or indicated in the invitation for bids. If not so stated, it will be assumed that none is desired.

3. For lines for water known to cause serious tuberculation it is recommended that pipe be not coated, and that it be lined with cement mortar.

4. Cast iron water pipe produced other than by the centrifugal method should not be purchased under this specification.

5. Centrifugally-cast iron pipe of lighter weight than specified herein, when required for exhaust or other low pressure lines, should be purchased on a separate specification.

6. When linings other than those specified in section IV–11 (*d*) are required, it should be so stated in the purchase order.

ZEOLITE WATER TREATMENT IN A LARGE CENTRAL HEATING PLANT[1]

By Alfred H. White;[2] J. H. Walker;[3] Everett P. Partridge;[4] and Leo F. Collins[5]

This paper describes a zeolite water treatment system in the Beacon Street heating plant of The Detroit Edison Company. It gives the results of some extensive preliminary laboratory investigations, carried on at the University of Michigan, to determine the possibilities of the removal of carbon dioxide from a zeolite-treated water by means of sulphuric and phosphoric acids. Some actual operating results are also included.

The matter of feedwater treatment is of extreme importance in a central heating plant. Recent developments in boiler design and firing methods have made possible very great increases in rates of driving, with consequent reductions in investment costs. Most of these developments have originated in electrical generating stations using distilled water or at least a high percentage of recirculated water. In a central heating plant the advantages of high steaming rates are at least equally great, but the necessarily large amount of make-up water in such a plant (very little condensate being returned from the consumers' buildings) makes the successful attainment of such steaming rates very difficult. The feedwater treatment thus becomes of primary importance and if, through the production of a better water, any particular method of treatment makes higher steaming rates possible, then the reduction thus brought about in the entire plant investment far over-balances any possible increased cost of installing and operating the treating system.

[1] Presented before the Boiler Feed Water Studies session, Chicago Convention, June 8, 1927.

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[5] Chemist, The Detroit Edison Company, Detroit, Mich.

The primary consideration in the selection of a treating system for this heating plant was that it produce as nearly a scale-free water as possible. A deposit of scale of even eggshell thickness in boiler tubes which are directly exposed to severe radiant heat will so impede heat transfer as to cause overheating and failure of the tube wall; and it is the unfortunate characteristic of the worst scale forming materials that their decreasing solubility with increasing temperature causes them to precipitate on these hottest tube walls.

CHOICE OF A TREATMENT SYSTEM

The Beacon Street heating plant is the newest of the four plants which supply steam for heating in the central business district of Detroit. It is designed to contain, eventually, twelve boilers of 41,500 square feet of surface, each, and capable of being operated at 300 per cent of rated capacity—a steam output of 406,000 pounds per hour per boiler. These boilers, by he way, are the largest yet built as to evaporating surface, though not as to steam output.

The make-up water is taken from the city water mains. The Detroit water supply is taken from the Detroit River at the foot of Lake St. Clair and is filtered. A typical analysis (March, 1926) is as follows:

	parts per million
CO_2 (free)	1.8
SiO_2	6.4
Fe_2O_3	2.0
Ca	25.7
Mg	7.3
Na and K	Not determined
HCO_3	75.6
CO_3	0.0
SO_4	31.1
Cl	7.7
Total solids (by evaporation)	121.0

This is a rather soft water and external treatment had never been considered necessary in the existing heating plants, operated at lower steaming rates, although internal treatment with sodium carbonate had been used for several years.

Consideration was given to several methods of treatment before the selection of zeolite was finally made. Internal treatment with

sodium carbonate, using the control methods devised by R. E. Hall[6] was one possibility. It had recently been used with some success in the older and smaller heating plants and has the advantage of requiring very little equipment. However, it produces large quantities of carbonate sludge in the boiler, does not entirely prevent the formation of certain silicate scales, and produces a high caustic alkalinity in the boiler.

Tri-sodium phosphate had also been used successfully, but it is open to similar objections. The resulting caustic alkalinity is somewhat lower than with sodium carbonate treatment, although at the operating pressure of 150 pounds the difference is not as great as at higher pressures.

Barium salts because of their poisonous nature were ruled out as a matter of public policy due to the fact that steam supplied by the plant is used for cooking purposes.

The hot process lime and soda system was carefully considered and its choice would have been a conservative decision. To the engineers responsible for the design and operation of the plant it did not appear, however, that this treatment would invariably produce a scale-free water; and the hot sedimentation tanks which are a necessary part of such a system would have been costly and awkward, since the plant is designed for an ultimate output of 4,000,000 pounds of steam per hour with about 90 per cent make-up water.

The zeolite system as finally chosen is open to the theoretical objection that it does not remove the dissolved solids but merely converts them to more soluble salts, thus causing high concentrations of solids in the boiler and requiring a large amount of blow-off. Another objection is that with a bicarbonate water such as that in Detroit the sodium bicarbonate produced by the treatment unless removed by an after-dose of acid would ultimately cause a high caustic alkalinity in the boiler. As a means of preventing scale formation, however, it appeared that the zeolite system would be certain of results and operating experience has confirmed this conclusion. With the calcium and magnesium almost totally removed, the potential scale-forming elements are largely disposed of and the possibility of the small residue of these materials depositing as sulphate scale is probably prevented by the presence of sufficient carbonate ions, if Dr. Hall's conclusions are correct.

[6] A Physico-Chemical Study of Scale Formation and Boiler Water Conditioning. Bulletin No. 24, Carnegie Institute of Technology.

The large amount of blow-down is prevented from being a serious source of heat loss by the continuous extraction of a small amount of water which is passed through a heat exchanger where the heat is transferred to the colder supply water. The waste of the water itself however cannot be economically prevented.

REASONS FOR ACID TREATMENT

The high caustic alkalinity in the boiler resulting from the use of a zeolite system with a water which is high in bicarbonates demands consideration of the possibility of embrittlement of the boiler steel.[7] Although no attempt was made to pass judgment upon this as yet unsettled point, it was thought prudent to add the required quantity of inhibiting sulphate ions suggested by Professor Parr and others. For this reason the plan was adopted of treating the water after passage through the zeolite bed with a carefully graduated dose of sulphuric acid.

There was a further requirement imposed upon the treating system which would be met by the use of this acid feed. With a bicarbonate water the steam leaving the boiler is ordinarily contaminated with carbon dioxide and one of the objects sought was the reduction of this gas content. The slow corrosion which has occasionally been observed in the pipes and radiators of consumers' heating systems has been thought to be partially due to the presence of this gas along with oxygen and there is some evidence to support this view.[8] The addition of acid to the zeolite-treated water would serve to liberate an equivalent amount of carbon dioxide, and if the water were passed through a deaerator before going to the boiler the free carbon dioxide would be removed along with the oxygen. Some of the remaining bicarbonate would also be broken up. The addition of sulphuric acid is more effective in increasing the sulphate-carbonate ratio than would be the addition of a sulphate salt because it removes carbonate ions as well as adding sulphate ions; and although the primary purpose of the acid is the inhibition of caustic embrittlement, its use also makes it possible to reduce the carbon dioxide

[7] The Cause and Prevention of Embrittlement of Boiler Plate. By S. W. Parr and F. G. Straub. Bulletin No. 155, Engineering Experiment Station, University of Illinois.

[8] Reports of Corrosion Committee, Proceedings of the National District Heating Association, 1924 and 1925.

content of the resulting steam approximately in proportion to the amount of acid fed. The use of acid following a zeolite treatment is not new, but the method of application possesses some novel features and it has probably not been used heretofore on such a large scale nor accompanied by quantitative studies of its effects.

The limits to the amount of acid to be fed could not be set clearly from theoretical considerations. There were two points to be guarded against in the introduction of sulphuric acid:—one the danger of corrosion due to an acid water, and the other the possible deposition of sulphate scale if the concentration of the carbonate was reduced to too low a point. The use of phosphoric acid offered some attractive possibilities as a supplement to sulphuric acid because of its lesser corrosive action and the flocculent nature of calcium phosphate which does not form a hard scale. The obvious disadvantage of phosphoric acid lay in its higher cost.

EXPERIMENTS ON THE EFFECT OF ACIDIFICATION AND ON ELIMINATION OF CO_2

Experimental laboratory work was first undertaken on waters containing $Ca(HCO_3)_2$, and the changes in such waters on boiling subsequent to additions of varying amounts of acid were studied. Similar tests were made on water which was of the type of Detroit city water after zeolite treatment; that is, water in which sodium bicarbonate is the main salt in solution. Since this paper discusses the process as actually installed in the Beacon Street plant, the only experimental data given here deal with tests on water similar to that coming from a zeolite softener. The water was treated with various amounts of acid and then heated to determine the amount of carbon dioxide evolved and the resultant changes in the acidity of the water. The laboratory tests were made in glass flasks in which the water was kept at boiling temperature, at atmospheric pressure, with the volume of water kept constant. In a boiler this constancy of volume is maintained by the introduction of new water but the adoption of this procedure in the laboratory would have prevented the study of the progressive changes which occur when a definite initial mass of water is boiled. The figures thus obtained are not strictly comparable with those obtained in boiler practice. They do, however, afford a valuable indication of the results to be expected in actual operation and the conclusions drawn from them have been largely borne out in practice.

The laboratory process approximates the conditions existing in an open feed-water heater intended for deaeration. Steam at atmospheric pressure is passed through the water being tested, which is contained in a flask jacketed in boiling water to prevent undue condensation. The steam leaving the water carries with it carbon dioxide. By passing this steam through a condenser and discharging the condensate into barium hydroxide, the amount of carbon dioxide removed from the water was found for successive increments of steam used. The actual technique is somewhat involved, in order to guard against loss of carbon dioxide and the influence of the small amount of that gas present in the atmosphere. Since the laboratory apparatus does not allow as intimate contact between the steam and hot water as does a commercial deaerator, the actual results in the plant were somewhat better, as will be shown later.

One part of the investigation was conducted, before the zeolite system was finally chosen, on an artificial water of approximately the same concentration of sodium bicarbonate as zeolite-treated Detroit water. This water contained 70 parts per million of combined carbon dioxide. The rate of removal of the carbon dioxide was first determined for samples acidified to varying degrees with tenth-normal sulphuric acid, and then the curves for samples treated with the same amounts of tenth-normal phosphoric acid were obtained.

Another part of the experimental work, conducted after the plant was in operation, was to determine the rate of evolution of carbon dioxide from a water which had been through the zeolite softener and had been partially acidified with sulphuric acid in the regular feed-water treatment of the Beacon Street plant. It was desired to know the ultimate possibilities of the breaking up of sodium bicarbonate by continued steam treatment.

The hydrogen-ion concentration of the water was measured in each case, first, after the addition of the acid, and, second, after the removal of carbon dioxide had been carried nearly to completion. LaMotte colorimetric standards were used for this work.

CO_2 REMOVAL AND FORMATION OF NaOH

The carbon dioxide removal curves for both parts of the investigation are shown in the accompanying figures. Figure 1 shows the actual experimental results, plotted as parts per million of carbon dioxide removed against amount of steam passed through the water,

expressed in per cent of the amount of the water sample. The curves of figures 2 and 3 show the parts per million of combined carbon dioxide left in the water for any per cent of steam passed through it. Figures 1 and 2 refer to the samples of treated water from the Beacon

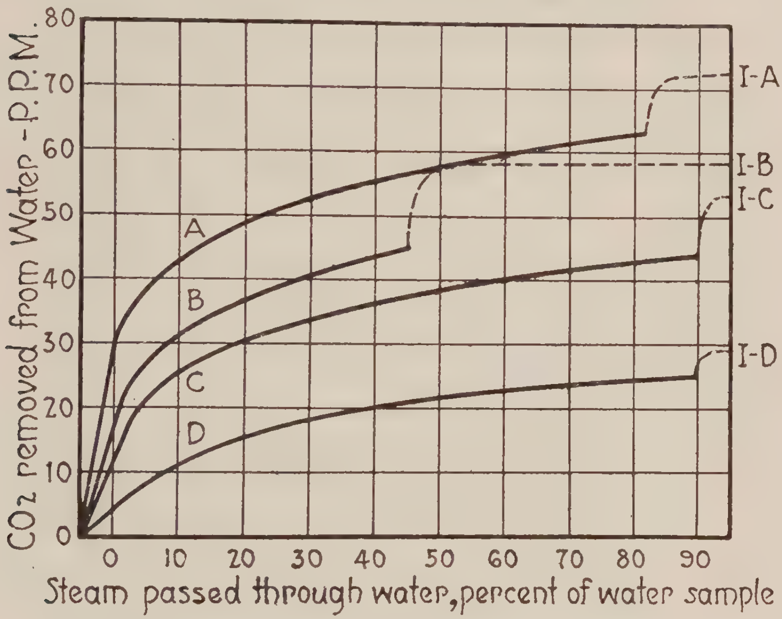

FIG. 1. LABORATORY TESTS ON THE REMOVAL OF CO_2 FROM THE ZEOLITE-TREATED AND PARTIALLY NEUTRALIZED FEED WATER OF THE BEACON STREET PLANT

The parts of the curves to the left of the zero point show the elimination of CO_2 while the water was being heated to the boiling point. The dotted lines indicate the changes caused by the addition of excess acid near the end of a run for the purpose of liberating all of the CO_2 remaining in the water.

Curves A, B, and C were made from the same sample of partially neutralized but not deaerated water, which had lost part of its CO_2 by standing in the air one week in the case of B, and two weeks in the case of C.

Curve D was made on water which was taken from the outlet of the deaerator at the Beacon Street Plant.

Street plant and figure 3 to the artificial sodium bicarbonate water prepared in the laboratory.

Four curves are shown in figure 1. Of these, the upper three represent the rate of removal of carbon dioxide from the zeolite-softened

and acidified, but not deaerated, water taken from the Beacon Street plant. Curve A was made immediately upon receipt of the water sample, when the total carbon dioxide content was 72.5 parts per million. Curve B was made after an interval of a week, during which the water sample had been standing in the laboratory. The total

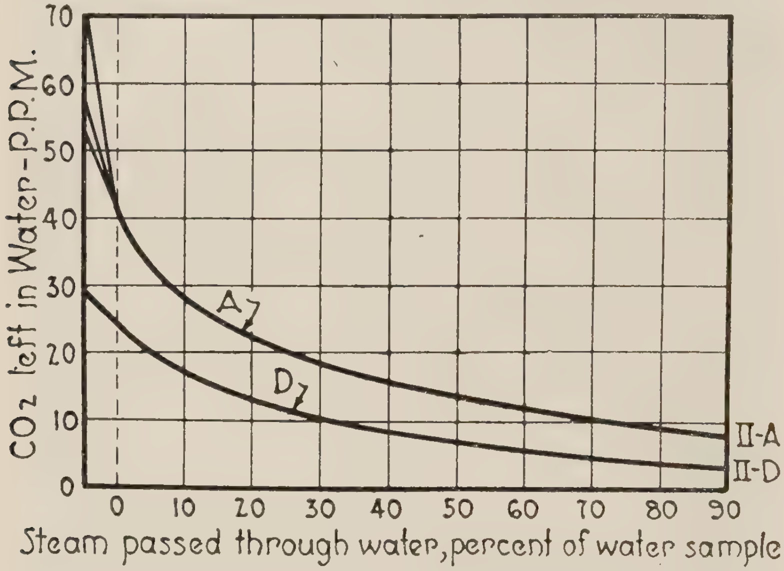

FIG. 2. RESIDUAL TOTAL CONTENT OF CO_2 OF THE ZEOLITE-TREATED AND PARTIALLY ACIDIFIED WATER OF THE BEACON STREET PLANT AS SHOWN ON LABORATORY TESTS

These curves are from the same data as those of figure 1.

Curves A, B, and C of figure 1 fall so closely together that they are combined as one curve to the right of the vertical zero line. These represent the partially acidified water which had been allowed to lose varying proportions of its inital CO_2 by standing in the air. Curve D represents the changes in the water which was taken from the outlet of the deaerator.

$$2NaHCO_3 + xH_2O \rightleftarrows Na_2CO_3 + CO_2 + (x + 1)\ H_2O$$
$$Na_2CO_3 + xH_2O \rightleftarrows 2NaOH + CO_2 + (x - 1)\ H_2O$$

carbon dioxide content at this time had dropped to 58.4 parts per million. Curve C was determined after the water had been standing in the laboratory a second week. At this time the water contained 53.0 parts per million total carbon dioxide. By referring to figure 2 it will be seen that the three curves from figure 1, when plotted as

residual carbon dioxide in the water, fall closely together in Curve A. This seems to point conclusively to the fact that the free carbon dioxide dissolved in water, whether derived from equilibrium with

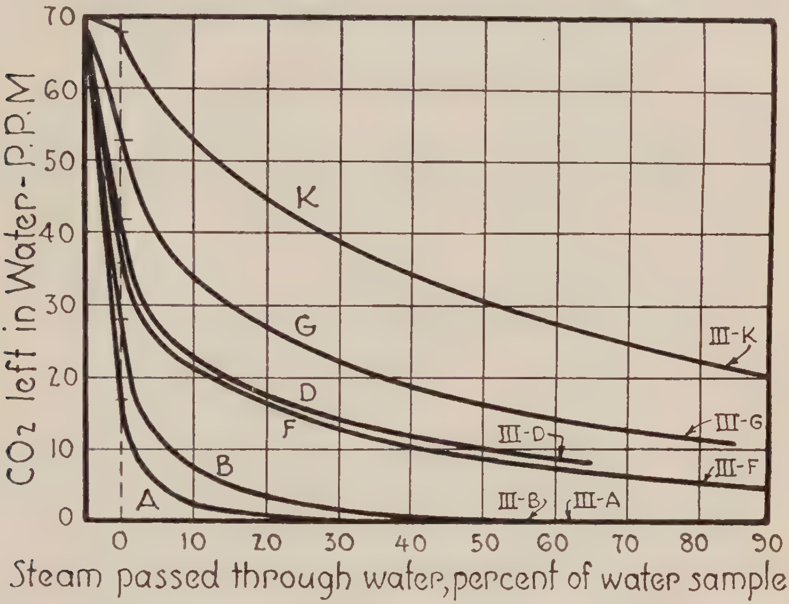

FIG. 3. RESIDUAL TOTAL CO_2 CONTENT OF $NaHCO_3$ WATER, AFTER NEUTRALIZATION TO VARIOUS DEGREES WITH H_2SO_4 OR H_3PO_4 AND DEAERATION TO VARIOUS DEGREES IN LABORATORY APPARATUS

The parts of the curves to the left of the vertical zero line show the elimination of CO_2 while the water was being heated to the boiling point.

CURVE NUMBER	ACID USED	N/10 ACID PER 500 CC. WATER	PER CENT OF COMPLETE NEUTRALIZATION	pH OF WATER ON ADDITION OF ACID	pH OF WATER AFTER CO_2 REMOVAL
		cc.	*per cent*		
A	H_2SO_4	7.5	94.0	5.7	8.75
B	H_3PO_4	11.25	94.0	6.4	8.5
D	H_3PO_4	7.5	62.5	6.65	*
F	H_2SO_4	5.0	62.5	6.3	*
G	H_3PO_4	5.0	41.6	6.85	*
K	None	None	0.0	8.25	*

* pH above 8.8 beyond range of available indicator standards.

the carbon dioxide of the atmosphere, or from the neutralization of bicarbonate by the addition of acid, is removed very rapidly on heating the water, and that the subsequent rate of removal of carbon dioxide is dependent on the rate of hydrolysis in the reactions:

$$2NaHCO_3 + xH_2O \rightleftarrows Na_2CO_3 + CO_2 + (x + 1)\ H_2O$$
$$Na_2CO_3 + xH_2O \rightleftarrows 2NaOH + CO_2 + (x - 1)\ H_2O$$

Curve D of figure 1 represents a series of runs made on feedwater from the Beacon Street plant which had been zeolite-treated, partially acidified with H_2SO_4 and passed through the Cochrane de-

TABLE 1

Changes in character of alkalinity of feedwater of Beacon Street Plant upon further removal of CO_2 by passing steam through the water

	CO_2				NaOH
	Free	Bicarbonate	Carbonate	Total	
	p.p.m.	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*
Initial water—city mains (winter)[1]	6.0	70.0	0.0	76.0	0.0
Acidified water[1]	47.0	29.0	0.0	76.0	0.0
Deaerated water[2] as received	0.0	25.0	2.0	27.0	0.0
Deaerated water[2] + 10% additional steam treatment in laboratory	0.0	5.0	12.0	17.0	0.0
Deaerated water[2] + 20% additional steam treatment in laboratory	0.0	0.0	13.5	13.5	1.8
Deaerated water[2] + 100% additional steam treatment in laboratory	0.0	0.0	2.5	2.5	21.8

[1] From data obtained by The Detroit Edison Company.

[2] From the laboratory tests.

aerator in accordance with present practice. The total carbon dioxide content of this deaerated water was 27.0 parts per million. Since the water was alkaline to phenolphthalein, none of this was present as free carbon dioxide. In figure 2 the same results are expressed in curve D. It will be seen from this group that further removal of carbon dioxide from the deaerated water is still fairly rapid for the first part of the curve, the residual carbon dioxide in the water being decreased from 27 to 17 parts per million for 10 per cent additional steam used. Thus it appears that by supplementing the present deaerating process by passing additional steam through the water, the carbon dioxide could be removed to a greater degree.

In the following tables, table 1 shows the condition of the water at the various steps in the present treatment and possible further treatment with excess steam. The formation of caustic soda took place in the laboratory experiments during the steam treatment. In the plant, however, it takes place only in the boiler. The result is, however, merely dependent on the time of reaction and the continuous removal of carbon dioxide. Pressure is not necessary.

TABLE 2

Changes in character of alkalinity of $NaHCO_3$ water upon removal of CO_2

AMOUNT OF ACID TREATMENT	STEAM THROUGH WATER	CO_2 REMOVED	RESIDUAL ALKALINE SUBSTANCES		
			$NaHCO_3$	Na_2CO_3	NaOH
	per cent	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*
No acid added to water	0	0	133.7	0.0	0.0
	10	17	68.8	41.0	0.0
	25	27	30.6	65.1	0.0
	50	39	0.0	74.6	7.3
	100	50	0.0	48.1	27.3
	Infinite*	70	0.0	0.0	63.7
H_2SO_4 or H_3PO_4 = 43.8 p.p.m. free CO_2 added to water	0	(35)	50.0	0.0	0.0
	10	50	26.3	15.0	0.0
	25	56	3.4	29.4	0.0
	50	61	0.0	21.7	7.5
	100	65	0.0	12.1	14.7
	Infinite*	70	0.0	0.0	23.8
H_3PO_4 = 65.6 p. p. m. free CO_2 added	0	42	8.4	0.0	0.0
	10	61	8.4	0.0	0.0
	25	68	0.0	4.8	0.4
	50	70	0.0	0.0	4.0
H_2SO_4 = 65.6 p. p. m. free CO_2 added	0	52	8.4	0.0	0.0
	10	68	0.0	4.8	0.4
	25	69	0.0	2.4	1.9
	50	70	0.0	0.0	4.0

* Calculated for complete decomposition by hydrolysis.

Results of laboratory tests made on a sodium bicarbonate solution containing 133.7 parts per million $NaHCO_3$ equivalent to 70.0 parts per million CO_2. Tests made at atmospheric pressure by passing various percentages by weight of steam through the water maintained at the boiling point.

The effect of the addition of different quantitites of sulphuric and

phosphoric acids as well as duration of boiling on a water containing only sodium bicarbonate is shown in table 2, figure 3 and figure 4. The rate of removal of CO_2 is studied most conveniently in figure 3 which shows in curve A that after the addition of sulphuric acid in amount sufficient to liberate 65.6 of the 70 parts per million

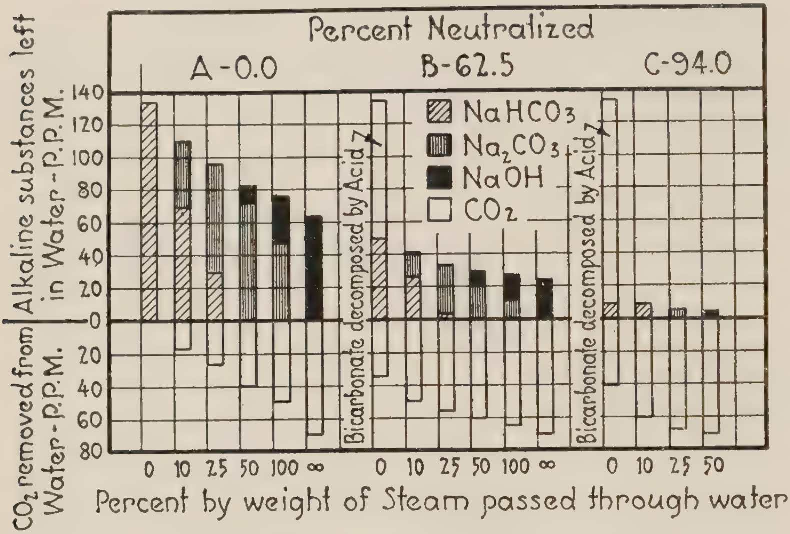

FIG. 4. CHANGES, UPON REMOVAL OF CO_2, OF CHARACTER OF ALKALINITY OF WATER CONTAINING $NaHCO_3$ AFTER NEUTRALIZATION TO VARIOUS DEGREES

These graphs are from the same data as figure 3. The columns marked with the infinity symbol represent the theoretical condition after complete removal of CO_2.

$$NaHCO_3 + H_2SO_4 \rightleftarrows NaHSO_4 + H_2O + CO_2$$
$$NaHCO_3 + NaHSO_4 \rightleftarrows Na_2SO_4 + H_2O + CO_2$$

$$NaHCO_3 + H_3PO_4 \rightleftarrows NaH_2PO_4 + H_2O + CO_2$$
$$NaHCO_3 + NaH_2PO_4 \rightleftarrows Na_2HPO_4 + H_2O + CO_2$$
$$NaHCO_3 + Na_2HPO_4 \rightleftarrows Na_3PO_4 + H_2O + CO_2$$

CO_2 the amount of CO_2 left in the water when it reached the boiling point had dropped to 17 parts and after 5 per cent steam had passed through the residual CO_2 was only 4 parts. Practically complete removal of the CO_2 came when 40 per cent of steam was passed through the water.

The changes in alkalinity of the water with partial neutralization

and subsequent boiling are best followed in figure 4. It will be noted that the laboratory bicarbonate water contains 133.7 p.p.m. $NaHCO_3$ and no other compound than $NaHCO_3$ but that after it has been heated to boiling and 10 per cent by volume of steam has been passed through, that 17 p.p.m. of CO_2 have been evolved and that the water, whose volume has remained constant, now contains 41.0 p.p.m. $NaHCO_3$ and 68.8 $NaHCO_3$. After 50 per cent by volume of steam has been blown through the water, the $NaHCO_3$ has all been broken up and there is left 74.6 p.p.m. Na_2CO_3 and 7.3 NaOH. If the process were continued long enough, there would be only NaOH left in the water.

The effect of partial acidification is also shown in figure 4. The CO_2 displaced by the acid is evolved promptly and the residual $NaHCO_3$ is decomposed at the same rate as before. The effect of acid in cutting down the quantity of NaOH which can appear in the water is shown quite strikingly.

COMPARISON OF H_2SO_4 AND H_3PO_4 AS ACIDIFYING AGENTS

The curves in figure 3 show that H_2SO_4 and H_3PO_4 have substantially the same value for neutralizing $NaHCO_3$ provided only two of the three hydrogen atoms of H_3PO_4 are considered as being available for this purpose. This relation may be explained by considering the reaction of each of these acids with sodium bicarbonate, the latter substance being in excess.

The sulphuric acid reaction may be written in two steps:

$$NaHCO_3 + H_2SO_4 \rightleftarrows NaHSO_4 + H_2O + CO_2$$
$$NaHCO_3 + NaHSO_4 \rightleftarrows Na_2SO_4 + H_2O + CO_2$$

Both reactions will always go substantially to completion, since $NaHSO_4$ is stable only in solutions of low pH, while $NaHCO_3$ produces a pH greater than 8.0 even in extremely dilute solution.

With phosphoric acid a similar series of reactions take place.

$$NaHCO_3 + H_3PO_4 \rightleftarrows NaH_2PO_4 + H_2O + CO_2$$
$$NaHCO_3 + NaH_2PO_4 \rightleftarrows Na_2HPO_4 + H_2O + CO_2$$
$$NaHCO_3 + Na_2HPO_4 \rightleftarrows Na_3PO_4 + H_2O + CO_2$$

In this case, the first sodium salt formed is stable at a pH of 4.5 and, therefore, cannot exist in the presence of excess $NaHCO_3$ with its much higher pH. The second sodium salt, however, the di-sodium phosphate, is stable at a pH of approximately 9.0 and therefore

will not react with an excess of sodium bicarbonate. The third hydrogen atom of phosphoric acid, is, therefore, not available for decomposition of sodium bicarbonate.

When compared on this basis the acids act so similarly that a difference hardly appears when plotted on the scale of figure 3 which gives a few representative curves. It may be noted that curve A obtained with H_2SO_4 shows a more rapid reaction in the first stages than curve B with H_3PO_4. This may probably be ascribed to a slight lag in the second reaction of mono-sodium phosphate with sodium bicarbonate.

In the reaction of phosphoric acid with sodium bicarbonate there exists an equilibrium between the various salts. For the sake of simplicity, the transition from salt to salt has been assumed to be abrupt. Actually, at a pH of 4.5 only mono-sodium phosphate is present, and at a pH of 9.0 only di-sodium phosphate is present. At any intermediate pH, however, both salts are in equilibrium, while below 4.5 mono-sodium phosphate is in equilibrium with free acid, and above 9.0, di-sodium phosphate is in equilibrium with tri-sodium phosphate.

Since only two of the three acid hydrogen atoms of phosphoric acid are available for neturalization of sodium bicarbonate and since tenth-normal acids are made up to contain one-tenth of a gram of formula hydrogen per liter, it requires 50 per cent more phosphoric acid than sulphuric acid of a given normality to achieve the same results. Calculated on a molecular rather than a normal basis, equimolecular concentrations of phosphorie acid and sulphuric acid will have equal neutralizing effects on sodium bicarbonate. Since the formula weights of H_3PO_4 and H_2SO_4 happen to be identical, it follows that one pound of 100 per cent phosphoric acid will be equal to one pound of 100 per cent sulphuric for neutralization of a bicarbonate solution. Sulphuric is much the cheaper acid and therefore there is, so far, no reason for using phosphoric. If, however, we consider the pH produced in a bi-carbonate solution by addition of a given amount of sulphuric acid, and compare it with the pH produced by an amount of phosphoric acid of equal neutralizing effect, the advantage of phosphoric acid in this respect becomes apparent.

This comparison may be made by reference to the data accompanying figure 3. Curve A represents the removal of carbon dioxide from the sodium bicarbonate solution when neutralized with 94 per cent of the theoretical amount of tenth-normal sulphuric acid, while

curve B shows the CO_2 removal for the corresponding amount of phosphoric acid. It will be noted that the initial pH produced by the addition of 7.5 cc. of tenth-normal sulphuric acid was 5.7, while that produced by the effective equivalent of tenth-normal phosphoric acid, 11.25 cc., was 6.4. In both cases after practically complete removal of carbon dioxide the pH had shifted back to a high value, 8.75 for the solution treated with sulphuric acid and 8.5 for the solution treated with phosphoric acid. The higher initial pH and lower final pH produced by the phosphoric acid is due to the buffer action of the sodium salts of phosphoric acid, commonly utilized in making solutions of standard pH. Addition of acid or alkali to an equilibrium between sodium salts of phosphoric acid is partially offset by a

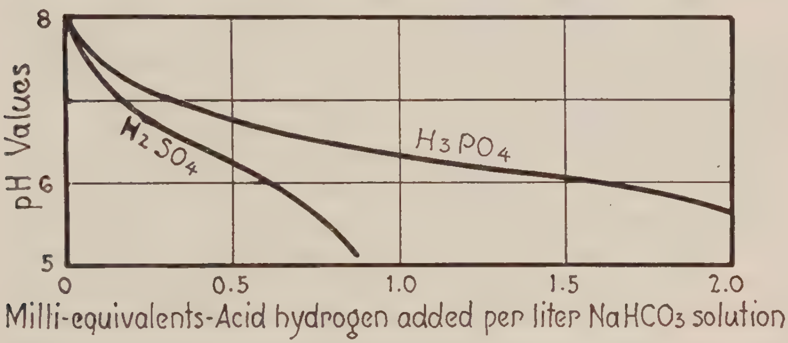

Fig. 5. Effect of Additions of H_2SO_4 and H_3PO_4 on pH of Water Containing $NaHCO_3$

readjustment of the ionic equilibrium in the direction of constant hydrogen-ion concentration.

The ideal boiler water should be neither acid nor alkaline. If enough H_2SO_4 is added to a bicarbonate water to release all of the CO_2 the water will be acid and corrosive as it goes to the feed-water heater though it will be neutral as it comes from it. If too little H_2SO_4 is added, the water will go from the feed-water heater to the boiler containing $NaHCO_3$. By using H_3PO_4, the bicarbonate content may be neutralized completely with the production of an only slightly acid pH in the water going to the feed-water heater. Furthermore, any accidental slight excess of phosphoric acid will be much less harmful than a similar excess of sulphuric acid, since the buffer action of the sodium phosphate salts tends to counteract the decrease in pH.

The actual pH values produced by adding various amounts of sulphuric or phosphoric acid to a sodium bicarbonate solution were determined on a water of approximately one-half the concentration with respect to sodium bicarbonate of the zeolite-treated water of the Beacon Street plant. This would correspond roughly to the plant feed-water after the present acid treatment if it were allowed to lose its excess free carbon dioxide to the air. Figure 5 represents the plot of pH of the solution after addition of acid against the amount of acid added expressed as milli-equivalents per liter. The buffer effect of the sodium salts of phosphoric acid is evident in the relative amounts of phosphoric and sulphuric acid required to produce a given pH. These data allow a prediction of the pH which would be obtained in the zeolite-treated water for a given amount of treatment with either acid. However, since the water used for the determination of figure 5 has only half the concentration of $NaHCO_3$ of the zeolite-softened Beacon Street feed-water, the abscissae must be multipled by two if the curves are to be used in this way.

From the foregoing discussion it is seen that, if a more complete acid treatment were desired at the Beacon Street plant, this could be obtained more safely with an auxiliary feed of phosphoric acid, or with an increased mixed feed of sulphuric and phosphoric acids, rather than with sulphuric acid alone, since the additional phosphoric acid, while it would neutralize the remaining bicarbonate of the water and thus provide practically complete removal of carbon dioxide in the deaerator and would decrease the concentration of caustic in the boiler, would nevertheless not lower the pH of the water at any point in the system as much as would an equivalent amount of additional sulphuric acid.

ADVANTAGES OF PHOSPHORIC ACID IN PREVENTION OF CAUSTIC ALKALINITY

A solution of $NaHCO_3$, on boiling with continuous removal of the CO_2, breaks down into Na_2CO_3 and H_2O, which ultimately hydrolyzes into NaOH and CO_2. It has been noted that when H_3PO_4 is added to $NaHCO_3$, the reaction stops with Na_2HPO_4 in equilibrium with $NaHCO_3$ and that, therefore, only two-thirds of the available hydrogen has reacted. If now this solution of $NaHCO_3$ and Na_2HPO_4 be boiled with continuous removal of CO_2, the NaOH formed will react with the Na_2HPO_4 according to the reaction.

$$NaOH + Na_2HPO_4 \rightleftarrows Na_3PO_4 + H_2O$$

So long, therefore, as undecomposed Na_2HPO_4 is present, only a small amount of caustic alkalinity can build up in the boiler. There will be slight alkalinity due to the hydrolysis of the Na_3PO_4, but this will not increase with concentration of the salts in the water as does the concentration of NaOH due to decomposition of Na_2CO_3, because in the hydrolysis of Na_3PO_4 both the basic and acid reaction products stay in solution and continue to influence each other while in the hydrolysis of Na_2CO_3, the acid product, CO_2, is constantly removed from the sphere of the reaction.

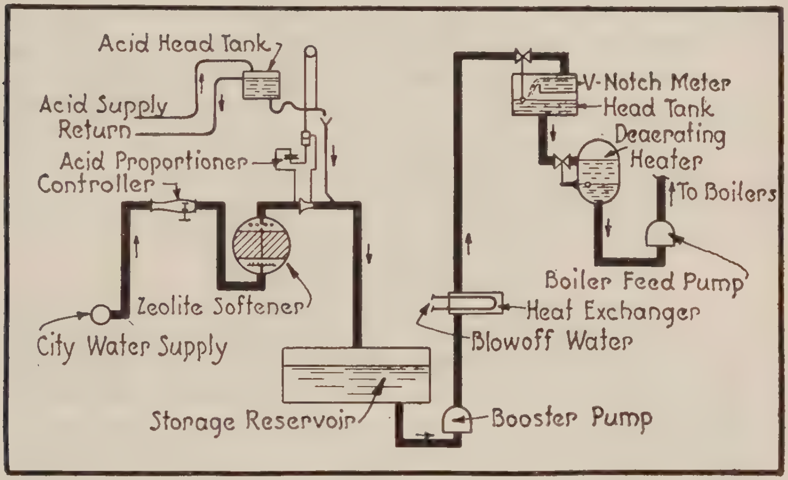

FIG. 6. DIAGRAM OF THE WATER CYCLE

DESCRIPTION OF THE TREATING SYSTEM AT THE BEACON STREET PLANT

The zeolite tanks are 10 feet in diameter and 25 feet long, set with their axes horizontal. They are constructed on the upward flow principle. The true relative merits of the up-flow and down-flow systems were found to be greatly obscured by patent difficulties and commercial considerations, but there seemed to be no fundamental objection to the up-flow system and operating experience has borne out this conclusion. The zeolite is of the green sand type, having a rated exchange value of 3375 grains per cubic foot. The zeolite bed is 41 inches thick and the rate of flow at normal load is

$4\frac{1}{4}$ gallons per minute per square foot of bed area. The total output per tank is 445,000 gallons between regenerations at the rate of 63,600 gallons per hour normal flow and with a maximum permissible flow of 75,000 gallons per hour. There are two of these tanks in the initial installation and the completed boiler plant will require a total of six tanks. The brine required for regeneration is supplied to the zeolite tanks through a simple piping system from a central overhead tank.

The water flows through the zeolite tanks under city water pressure. In order to insure a constant rate of flow which is essential in an up-flow system, regardless of fluctuations in pressure, a venturi type flow-controller is installed. After leaving the zeolite tanks the water is given the dose of acid and then flows into a concrete storage reservoir (see figure 6). Booster pumps lift it to a head tank from which it flows by gravity to the deaerating heater and boiler-feed pumps. The deaerating heater is of the Cochrane type. It contains a large number of trays over which the water flows and is swept by a counter-current of steam which removes the dissolved gases quite completely.

ACID FEEDING SYSTEM

The acid proportioning device feeds dilute acid in exact proportion to the amount of water treated. Although the water flow is maintained approximately constant by the controller and a fixed rate of acid feed might therefore have sufficed, it was nevertheless felt necessary to adjust the acid feed very exactly and to provide an automatic means of cutting off the feed when the flow of water stops. The proportioning device shown in figure 7 was therefore developed.

The acid is diluted to a two to three per cent solution in a central tank and is pumped through lead lined pipe to a constant level tank at each zeolite softener. To the bottom of each tank is connected a piece of rubber hose with a small orifice at its end, the elevation of which, with respect to the level in the tank, (marked h in figure 7) is controlled by a float resting on a column of mercury. This mercury level is controlled by a venturi nozzle placed in the water pipe leaving the softener. There is no stuffing box required and the float moves with practically no friction. Since the flow of acid through the orifice and the flow of water through the venturi throat are governed by a square root law the device gives almost

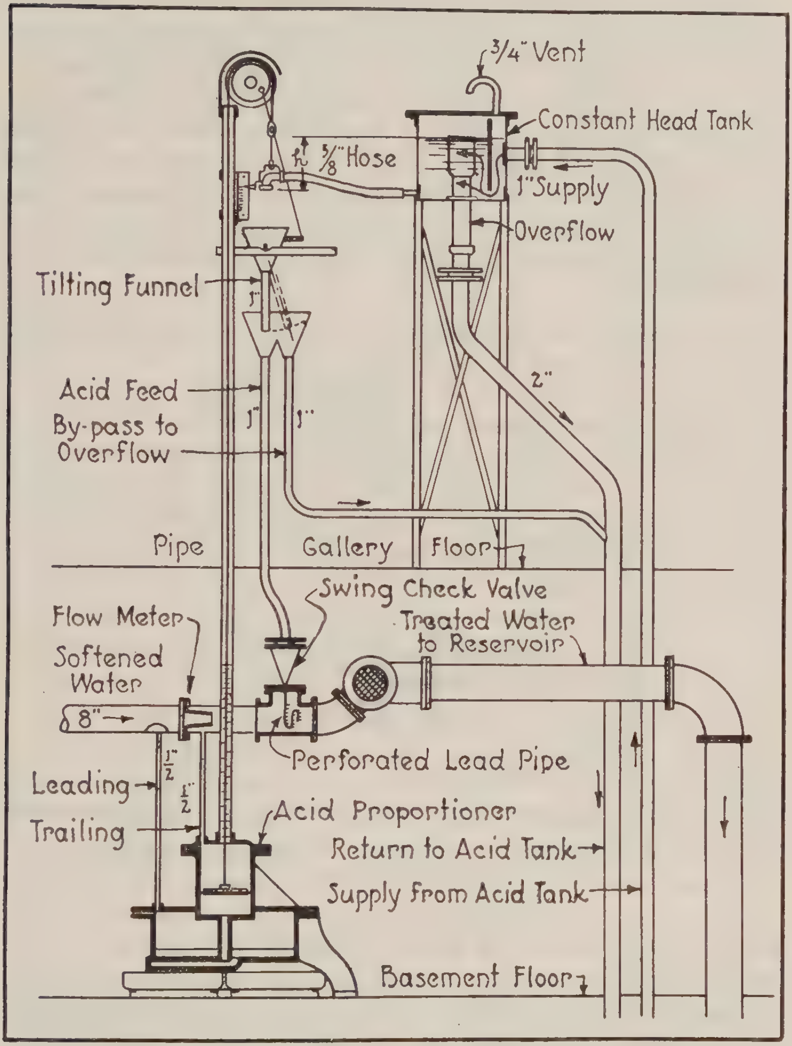

Fig. 7. The Acid-proportioning Device Which Controls the Flow of Dilute Acid in Exact Proportion to the Water Flow

exact proportioning, the only error being caused by the deflection of the lower leg of the mercury U-tube and this is made negligible by the relatively large diameter of this chamber.

The strength of the acid solution is so adjusted as to give the proper feedwater conditions. At present a three per cent solution is used and the ratio of the acid to the total boiler-feed is about 35 parts of 100 per cent H_2SO_4 per million of water. The condition of the water is recorded by a Leeds & Northrup hydrogen ion recorder which shows the pH value of the water in the storage reservoir and also as it leaves the feedwater heater. This apparatus is checked frequently by means of LaMotte colorimetric indicators. It is expected that after more experience is gained, this apparatus can be dispensed with.

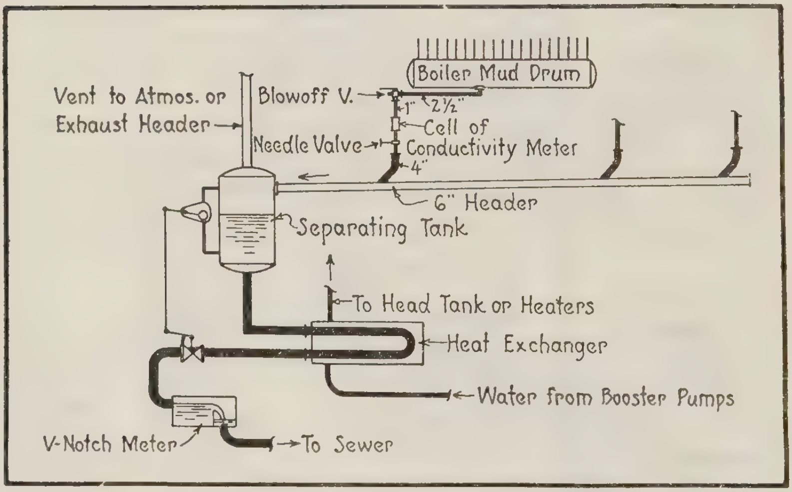

Fig. 8. Diagrammatic Arrangement of the Continuous Blow-off System

CONTINUOUS BLOW-DOWN

The blow-down at Beacon Street amounts to about 4½ per cent of the total boiler feed. The use of a continuous blow-down makes possible the extraction of the heat from the water and also gives more uniform steaming conditions than would the intermittent blowing off of large quantities of water.

The arrangement of the blow-down system is shown diagrammatically in figure 8. From each of the two mud drums of each boiler there is a one-inch line provided with a needle valve for controlling the flow. As the water passes through the needle valve there is

naturally a considerable amount of steam flashed off and this mixture of steam and water is conducted, through pipes of generous size, to a separating tank from which the steam is vented into the exhaust system of the plant which carries a pressure of about two pounds gauge. The water flows from the separating tank through the heat exchanger and V-notch meter and thence to the sewer. A float-controlled valve regulates the flow so as to maintain a constant water level in the separating tank. The cold supply water on its way to the heater passes through the heat exchanger, absorbing the heat from the blow-off water. The amount of blow-down is regulated by reference to a Leeds & Northrup recording conductivity meter, the cell of which is located in the blow-off line ahead of the needle valve. The electrical conductivity of the solution of salts in the boiler is a measure of the concentration, provided the kind of dissolved materials and their relative amounts with respect to each other remain the same. At present the concentration of dissolved solids is kept between 2,000 and 3,000 parts per million and the corresponding conductivity is from 3,400 to 3,700 reciprocal megohms. This standard has been established by experience with this particular water composition and boiler design. Further experience may permit the concentration to be increased.

OPERATING RESULTS

The system has been in operation since September, 1926. In general the desired results have been obtained. The maximum boiler loads for which the plant is designed were not called for during this first winter of operation, but under the existing load conditions, which called for 250 per cent of rating at times, there was no tube trouble and no formation of scale in the boilers.

The zeolite system produces water with an average hardness, expressed as $CaCO_3$, of less than three parts per million, this being somewhat better than the manufacturer's guarantee. The results of analyses of samples taken at various times during a run on one tank are shown in figure 9.

Table 3 shows the analyses of the water before and after treatment, and table 4 shows the condition of the water at several points in the cycle, using a feed of 35 parts per million of H_2SO_4.

The acid feeding methods have worked out satisfactorily. Very close supervision has been maintained, and of course an acid feed

will always require careful handling, but given such supervision there appears to be no danger of an over-dose of acid. There has been some trouble with the acid pumps and piping system which is no doubt due to lack of experience with this kind of equipment. It appears that the lead lined pipe is not entirely immune from attack by the dilute acid, and the lead pumps have not been entirely satisfactory.

With the normal feed of 35 p.p.m. H_2SO_4 the pH value of the water immediately after the acid feed is low (6.4), but after the water is passed through the deaerator it is increased to 8.5 due to the removal

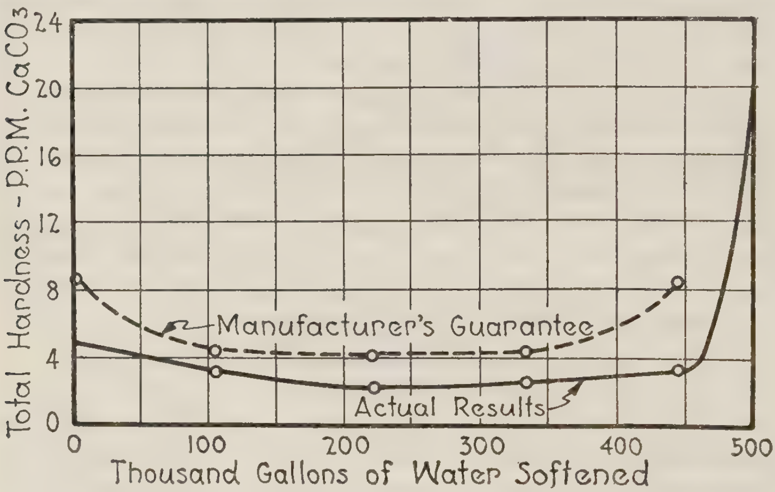

FIG. 9. CONDITION OF THE ZEOLITE-SOFTENED WATER AT VARIOUS INTERVALS DURING A RUN ON ONE OF THE TANKS

of the carbon dioxide, so that the water going to the boilers is well on the alkaline side. Referring to table 4 it will be noted that the acid reacts completely before the water enters the deaerator. The sodium bicarbonate is reduced from 120 to 60.5 p.p.m. by this reaction. In the deaerator the sodium bicarbonate is reduced from 60.5 to 38.0 p.p.m., a reduction of 37.2 per cent, producing an equivalent amount of normal sodium carbonate. This result is somewhat better than those obtained in the laboratory, and although further removal of carbon dioxide could probably be accomplished by steam treatment, it would hardly be justified and is not contemplated.

TABLE 3

Water conditions before and after treatment

All figures in parts per million

	RAW WATER	AFTER ZEOLITE	AFTER ACID FEED AND DEAERATION
Cations:			
Silica	3.0	5.1	5.1
Iron Oxide and Alumina	2.0	0.7	0.7
Calcium	26.4	0.8	0.8
Magnesium	6.4	0.2	0.2
Sodium	3.8	45.0	45.0
Anions:			
Sulphate	20.1	20.1	54.0
Chloride	5.9	5.9	5.9
Bicarbonate	87.0	87.0	27.5
Carbonate	0.0	0.0	9.0
Total dissolved solids	154.6	164.8	148.2
Hardness as $CaCO_3$ (gravimetric)	92.25	2.74	2.74

TABLE 4

*Water conditions at various points in the cycle**

Quantities in parts per million unless otherwise stated.

Acid feed—35 parts of 100 per cent H_2SO_4 per million parts of water treated.

	RAW WATER	AFTER ZEOLITE	AFTER ACID FEED	AFTER DEAERATOR	IN BOILER	STEAM
Temperature, °F	40.0	40.0	40.0	215.0	365.0	365.0
Pressure, pounds, ga	45.0	7.5			155.0	
pH value	7.6	8.6	6.4	8.5		5.4
CO_2 (free)	1.8		18.1	0.0	0.0	25.0
O_2, cc. per liter	6.03	6.03	6.03	0.016		0.044
$NaHCO_3$	0.0	120.0	60.5	38.0		
Na_2CO_3	0.0	0.0	0.0	14.2	174.0	
Na_2SO_4	0.0	30.0	81.0		1500.0	
NaOH	0.0	0.0	0.0	0.0	360.0	
Total alkalinity as Na_2CO_3					650.0	
$\frac{Na_2SO_4}{\text{Total alk. as } Na_2CO_3}$					2.3	
$\frac{SO_4}{CO_3}$					10.0	

* Average of 11 half-hourly readings.

The ratio of the sodium sulphate to the total alkalinity expressed as Na_2CO_3 (the ratio which is important, from the standpoint of caustic embrittlement) is also shown in table 4. The suggested minimum value for this ratio, for the steam pressure in this plant, is 1.0 so that the figure of 2.3 is well on the safe side. The maximum

TABLE 5

Water conditions with phosphoric acid feed[1]

Quantities in parts per million unless otherwise stated.

Acid feed 41 parts of 100 per cent H_2SO_4 plus 24.6 parts of 100 per cent H_3PO_4 per million parts of water treated.

	RAW WATER	AFTER ZEOLITE	AFTER ACID FEED	AFTER DEAERATOR	IN BOILER	STEAM
Temperature, °F.	40.0	40.0	40.0	215.0	365.0	365.0
Pressure, pounds ga.	45.0	7.5	7.5		155.0	155.0
pH value	7.6	8.4	5.8	8.8		5.4
CO_2 (free)	1.8	1.8	18.1	0.0	0.0	12.0
O_2, cc. per liter	6.03	6.03	6.03	0.016		0.044
$NaHCO_3$	0.0	116.0	24.2	14.6	0.0	
Na_2CO_3	0.0	0.0	0.0	4.1	143.0	
Na_2SO_4	0.0	30.0	88.5	77.5	1600.0	
$NaOH$	0.0	0.0	0.0	0.0	70.0	
NaH_2PO_4[2]	0.0	0.0	30.0	26.2	0.0	
Na_2HPO_4	0.0	0.0	0.0	0.0	225.0	
Total alkalinity as Na_2CO_3					236.0	
$\frac{Na_2SO_4}{\text{Total alk. as } Na_2CO_3}$					6.8	
$\frac{SO_4}{CO_3}$					13.2	
$\frac{SO_4}{PO_4}$					7.1	

[1] Average of 10 half-hourly readings.

[2] These combinations are calculated in the conventional manner and do not attempt to indicate the exact combinations which are present in the solution.

sulphate-carbonate ratio which is permissible under Hall's theory is 11.1 whereas the ratio actually maintained is 10. An increase of sulphuric acid feed would make the sulphate-carbonate ratio reach the value at which sulphate scale (in minute quantities) might be formed, and a decrease in the acid feed would bring the sodium sulphate-total alkalinity ratio toward the danger line of caustic

embrittlement. There is evidently a margin between these two somewhat conflicting requirements in which it is possible to stay.

RESULTS WITH PHOSPHORIC ACID

As a pure experiment, to determine the possibilities of further decreasing the CO_2 content of the steam, some phosphoric acid was used, for a short period, in addition to the sulphuric acid. The results are shown in table 5. With a feed of 41 p.p.m. of H_2SO_4 plus 24.6 p.p.m. of H_3PO_4, the carbon dioxide in the steam was reduced to 12 p.p.m. The pH value of the water after the acid treatment was 5.8 and that of the condensed steam was 5.4 Although the sulphate-carbonate ratio is above the limit suggested by Hall, the presence of PO_4 would prevent the formation of sulphate scale. The PO_4 content is 150 p.p.m., whereas a concentration of somewhat more than 4 p.p.m. should be sufficient.

These results indicate that it is entirely possible to control the carbon dioxide content of the steam by varying the acid feed and that the use of phosphoric acid for this purpose appears quite feasible, although experience with it has been very limited.

CONCLUSIONS

The zeolite water softening system operates satisfactorily and the acid feed, with careful supervision, appears to be quite practicable and reasonably safe.

The present addition of sulphuric acid sufficient to neutralize about 50 per cent of the $NaHCO_3$ in the zeolite treated water gives a pH value of 6.4 to the water entering the deaerator and a pH value of 8.5 to the water leaving the deaerator and entering the boiler.

The water leaving the deaerator has lost all of the CO_2 set free by the acid and the amount of $NaHCO_3$ which was 60.5 p.p.m. after the acid treatment has dropped to 38.5 p.p.m.

The continuous blow-down through a heat exchanger is satisfactory and the system of ionic control is effective.

The ratio of sodium sulphate to total alkalinity is believed to be amply safe with the amount of H_2SO_4 added.

Inspection of the boiler after eight months of operation has revealed clean tubes and no serious corrosion. There have been no tube burn-outs.

It has been demonstrated that the use of additional acid in the

form of phosphoric acid gives less carbon dioxide in the steam and less caustic alkalinity in the boiler. The necessity of thus reducing the carbon dioxide is not certain and will be justified only if the steam shows itself later to be corrosive with the smaller amount of acid feed. If scale ultimately appears in the tubes when only sulphuric acid is used, it is believed that the addition of a small amount of phosphoric acid will eliminate it.

DISCUSSION

J. R. Baylis: I was very much interested in this paper. It shows what might be done with water by chemical treatment. You can take the water and do almost anything you wish with it, but the thing that impressed me most was that any water having over 10 or 15 parts per million CO_2 needs some other treatment preliminary to zeolite treatment. The CO_2 can be very easily removed to 15 or 20 parts per million by perhaps a lime treatment, resulting in much less sodium. We might accomplish approximately the same thing, and get rid of any possibility of corrosive action of the high sulphates or chlorides in the water, before it is blown off.

R. E. Hall: I have been very much impressed by Mr. White's reference to the lesser acidity developed by phosphoric acid, because it opens up a large possibility in the acid treatment of waters, giving also the phosphate radical in the boiler water for the prevention of scale. One other point in the paper that is of especial interest is the figures on oxygen, low in boiler water and low in steam; figures that are within the error of experimental determination, but showing that the oxygen at this low figure is not retained by any action on the boiler metal even though the temperature there is high. One further point I wish to speak of is his certainty that with the phosphate radical in the water, no scale will develop. During the past summer an article appeared in which the use of phosphate, following in that case, I believe, a lime soda softener, was mentioned as giving a hard scale on the boiler. That had been totally outside of any experience that had come to me, and I have been rather waiting for some definite and exact data from totally outside sources that would meet this point. Professor White, in his work here, has given us the best exemplification of what phosphate can do in preventing scale, that we can have.

R. E. Greenfield: We have a system of lime soda treatment, followed by zeolite, with no acid neutralization. Mr. Baylis brought out the desirability of removing all of the calcium and magnesium possible with lime, thereby reducing the sodium salts in the boiler feed. I think that is a point very well worth taking into consideration. We have a water that would run very much like the water under discussion, but we get it from zeolite softeners, with only a matter of 50 or 60 parts per million of sodium salts, where Professor White is getting 155. That is the difference in the lime treatment, and that will cut down his acid feed, if he still wants to use that treatment. We have enough acid sulphate in our water to give the ratio of about 1 to 3. We have felt so far that we need not use acid feed on that account. We may use a little acid in order to protect the zeolite from the high alkalinity we now have, but at present it is not necessary because of the carbonate-sulphate ratio. We have had very good success with our system, although there is a little scale in our boilers, but we have been running three or four months, and the scale is not building up. We are not fortunate enough to have continuous blow-off.

O. W. Kerry: I would like to enquire as to the cost of the zeolite treatment, together with the acid treatment, and the approximate cost of the treating plant. What consideration has been given to just the use of soda ash in neutralizing the sulphate carried in the Detroit city water. We think the Detroit city water is a rather simple water to treat, and that scale can be prevented in boilers by the use of about one-half pound soda ash per thousand gallons, at a cost, at Detroit where they make a lot of soda ash, of around $\frac{1}{2}$ to $\frac{3}{4}$ of a cent per thousand gallons. There will be about a pound of sludge formed in the boiler per thousand gallons, but this sludge will be soft and may be readily blown out or washed out. I also notice in this pamphlet that with their continuous blow-down they keep the concentration at from 2000 to 3000 parts per million. That, I believe, represents a loss of about 4 per cent of the total water evaporated. With the use of soda ash, which, from our experience, will keep down scale formation when used at the rate of $\frac{1}{2}$ pound per thousand gallons, the blow-off should be at the rate of about 2 per cent in order to keep the foaming salts below the concentration at which the boilers would foam. Off hand it appears as though this water could be satisfactorily handled with the soda ash treatment

properly supervised, at a very economical cost. I would, like to inquire also as to the boiler pressure carried on the boilers and at what concentration the alkali salts can be carried in the boilers without foaming? That is, the highest concentration of alkali salts with which it is practical for the boilers to operate.

A. R. Moberg: What is the effect of alkalinity on the zeolite itself. The statement has been made a number of times that the high or excess alkalinities with the lime and soda treatment would be injurious to the zeolite. I have never seen any definite work done on it and I am wondering whether anybody else had done any work to determine whether it is the high alkalinity that is injurious to the zeolite or the chemical action of the lime itself that has a tendency to clog and coat the zeolite? I think that would have a large bearing on the use of lime and soda pre-treatment of zeolite.

A. S. Behrman: Mr. Kerry has raised one or two questions and Mr. Moberg has raised one or two more. Answering the last ones first, it is possible to use the lime-soda treatment before zeolite without intermediate neutralization, provided the treatment is properly carried out. Dr. Greenfield is having that experience now, I believe, and we have several plants under our observation which are operating with the proper lime-soda pre-treatment and which have been in operation long enough to establish the fact pretty thoroughly that there is not going to be any deleterious effect on the zeolite. To answer Mr. Moberg's second question, the principal difficulty which has been experienced, when the lime-soda treatment has not been carried out properly, has been from the active deposition and not from the effect of the alkali itself. We know that any strong excess of sodium carbonate or hydroxide will affect any zeolite deleteriously, but it is not necessary to have either of those conditions present.

Referring just for a moment to Mr. Kerry's suggestion that this matter in question could have been satisfactorily handled by soda ash alone, I am afraid that I echo the sentiments of a great number who disagree very radically with Mr. Kerry on that assumption. If the optimum results are to be attained, and that I take it was the object in Prof. White's work, not only scales should not be formed, but in general the most satisfactory boiler conditions should be obtained. The least one can expect from either a zeolite or a lime-soda softener, properly operated, is to produce no scales. If a zeolite or

lime-soda softener produces scales, the proper place for that equipment is in the lake or any other convenient dumping ground. It is no miracle of any water softening equipment to say that the boilers are free from scale. It is a reflection either on the equipment or on the operators if there is any scale. The objection to the soda-ash treatment alone for the given water in question, as for many waters, is the old story of sludge formed in the boiler. Without regulation of that situation, conditions arose which led some of the older railroads who have tried this treatment to abandon it in favor of complete external treatment when the water demand justified it. The soda ash treatment alone undoubtedly does a lot of good. It does not do nearly as much good in general as a complete treatment, as has been experienced with a number of the railroads here in the west and mid-west. Just one other point I want to raise, which Mr. Baylis has already raised, that is, with a water of this type, which is almost a straight carbonate water to start with, was the zeolite softener the proper device to use? As Mr. Baylis pointed out, the lime-soda treatment with a water of this type would have eliminated at the start, some of the considerations which had to be dealt with in the very efficient manner that Professor White and his colleagues have worked out.

J. H. Walker: A question was asked about the cost of the treatment. I have no figures but I can assure you that the cost per gallon is high. This matter is discussed in the paper, in which it is pointed out that, if a treatment could be secured which would give a scale-free water, the cost of the treatment was not an important consideration, because, if we can operate a boiler plant at 400 per cent of rated capacity, instead of 200 per cent of rated capacity, the saving in investment cost is very great. We have tried for two or three years a treatment consisting of a straight sodium carbonate treatment, following the lines suggested by Dr. Hall. In this plant we are unable to operate without scale. We have burned out some tubes at 225 per cent of boiler rating, whereas the new plant is designed for 300 per cent or higher. I would suggest that Dr. Hall be asked to speak again on this point, because he is familiar with our conditions at the other plants. The question was asked as to the operating pressure. It is 150 pounds gauge. Another question was asked about the permissible concentration which can be carried without foaming. To identify a foaming condition in a boiler

is a rather ticklish proposition. We had arrived at a concentration of salts which in other plants we had found to be the limiting condition. We have made no experiments in this plant as to whether we could carry a high concentration. It is quite possible we may be able to do so. In connection with the necessity for the acid treatment, we had had no cases of caustic embrittlement. We simply desired to profit by the experience which other people had reported. We had used the sodium carbonate treatment, and with that treatment had kept the suggested ratios of sulphate to carbonate so that we did not expect any caustic embrittlement. An examination of the boilers with this straight sodium carbonate treatment has never revealed any caustic embrittlement, but we are trying to guard against it. As boiler operators, we approached this matter of acid feed with a good deal of respect. We installed several mechanical safe-guards to prevent an overdose of acid, and we have very careful and continual supervision. After eight months of experience we do not really believe that our first fears were justified. The system seems to be reasonably safe, but of course constant supervision will always be required. I would like to propound a question, the answer to which I do not know. Zeolite treatment cuts down the calcium to 1 or 2 parts per million; on the other hand, with several millions pounds of water going into the boiler per day, if all the calcium that does go into the boiler were precipitated as calcium sulphate scale, it would be quite sufficient to cause tube burn-outs, because a very thin scale is all that is necessary for that. Now, does the zeolite treatment in itself produce the freedom from scale? Or is it rather because the relations of the various salts in the boiler are such that scale is not formed, in accordance with Dr. Hall's work?

R. E. Hall: I think I will answer Mr. Walker's last question first, as to the calcium. I cannot answer it on the basis of whether a zeolite treated water will not form scale, but with a reasonable blowdown, there is usually enough alkalinity or carbonate in the water, so that with the very low calcium present in the water, the concentrations will not rise high enough to lay down any of the sulphate scale. That is our viewpoint on that question. As to the question of the burn-out of the tubes which Mr. Walker has brought up, he is so exceedingly thorough in this matter of scale, that sections of tube give hardly enough scale to get a sample of a few grains for analysis. As I look at a tube of that kind, it was my contention that there was

not enough scale there to cause the burn-out, but Mr. Walker insists that if distilled water were in the boiler the tubes would not burn out, and his observation on that undoubtedly is correct. It brings us to the question of foaming in water. It has been our experience in the past year to run across in the lower row of tubes in the B. & W. boiler, scale that ran as high as 20% of sodium sulphate, and with sodium sulphate at 150 pounds pressure operation, soluble to the extent of 100,000 or 200,000 parts per million, it seems impossible that that scale can form unless that tube is practically filled with steam, that is, practically complete evaporation of such water as gets through it. It leads to the thought that these tubes must be filled with bubbles and that those bubbles are relatively small and of slow motion, preventing the heat exchange through the change of state of the water, and therefore allow almost complete evaporation of the surfaces of the bubbles that come in contact with the tube. A water contaminated even with low salt concentration in it, produces bad boiler conditions, and we think that the answer lies in that, rather than in anything else in these cases in which, with an exceedingly small amount of scale, burn-outs occur.

R. O. Friend: Answering the question raised regarding the cost of operation of the zeolite water softener installed at the Beacon Street Heating Plant of the Detroit Edison Company, the cost per 1000 gallons of water softened is 0.85 of a cent. This cost is based on the cost of salt delivered at the Beacon Street Heating Plant at $7.00 a ton.

A NEW JERSEY WATER CASE

By Louis L. Tribus[1]

Outside of a few of the larger cities, community water supply, in the generally accepted and understood sense, is covered by a period of not much over fifty years.

The village pump, the rain water fire cistern, the volunteer fire department with its hand power engine, private cisterns and occasional dug and driven wells, served needs of domestic supply and fire protection. Separated houses rarely over two stories, without sanitary conveniences, cared for the populations, and the wells served the family cooking, weekly bath (perhaps), the weekly washing, rinsing the milk buckets and occasional house and window cleaning, outside door steps and porches which always had attention. Streets alternated between dust and mud, and lawns, occasionally cut with a scythe, became green or brown as nature might dictate.

Intensive living had not brought its demands and luxuries, their greater responsibilities and doubtful larger happiness.

The Civil War of 1860–65 was succeeded by many revolutions in living and business and a growth entirely unanticipated—poverty and prosperity, panic and participation in world business. Present conditions are but a repetition on a much broader scale.

New Jersey, as one of the earliest settled states and rather intensively developed in the northern half, has presented many water problems for solution; practical, legal and legislative, in the matters of gathering, distributing and use for transportation, power, manufacturing, municipal and household life.

There has been much published as to the State's supplies for the future and much on record as to rates and diversion, so this paper will pass those topics.

There are five areas, each with its own peculiar conditions: The northeast, with its almost complete residential covering and interdependence of interests; the northwest, fairly mountainous, with

[1] Of Tribus and Massa, Consulting Engineers, New York, N. Y.

scattered towns, but no serious water deficiency at present; the northern coast settlements and their back districts, as yet fairly well supplied from underground sources; the southern coast cities and the southwestern, with Camden as the centre, both groups on the ragged edge of trouble.

This paper will be confined, however, to certain features of the first district, particularly the belt with Elizabeth at the east and Plainfield on the west. That belt takes in some 27 other communities with a population (combined) of some 200,000 or more; in fact, it is very largely one continuing city, spreading north and south of the Central R. R. of New Jersey.

In or about the year 1869 a state charter was granted to the Plainfield Water Supply Company to enable it to provide and sell potable water to the inhabitants of certain prescribed portions of Union, Somerset and Middlesex Counties—Plainfield being then the only fairly well settled part. In later years various county boundary changes were made but of no special import to this review. The Company made no practical use of its franchise until 1889, when it drove some 20 tube wells into the open gravels near Netherwood Station of the C. R. R. of New Jersey, some 2 miles from the centre of Plainfield and began erection of a steam pumping station and the laying of distribution pipes.

Financial troubles stopped the work, but new interests came to the rescue and a good plant was completed. (For description see Paper No. 700, Vol. 31, 1894. Trans. Am. Soc. Civ. Engrs.) Rates were promulgated at an average of terms charged at the same time in a number of the larger neighboring cities.

At about the same time, friendly interests organized the Union Water Company, which proceeded to lay mains in Union County outside of the charter district of the Plainfield Water Supply Company, and to supply such area with water purchased in bulk from the latter's plant at Netherwood. Later the two corporations united forces under the title "Plainfield-Union Water Company," but the source of supply continued as before, except that additional wells were driven and operated by air lift instead of direct suction, and a covered reservoir was substituted for standpipe service. The legality of this union will be referred to later in this paper.

The Elizabethtown Water Company had Elizabeth as its main centre of operations, although a couple of other smaller corporations, Piscataway and Raritan Township Companies, joined in its supply

and service. Several well systems together with the Elizabeth River furnished the water, the latter source being filtered.

The Middlesex Water Company developed a driven well plant at South Plainfield and a surface supply on Robinson Branch of Rahway River.

In 1920 (the last year of full statistics available) about 31,000,000 gallons were being pumped daily by the combined group of companies, whose interests were so fully in common.

Several million gallons per day more were self-served by manufacturing companies who drilled wells for themselves, not always however with much success. The near-surface gravels of the glacial moraine yield a good flow of water and the underlying red shales some more, but the clays so abundant throughout the tributary water sheds do not yield much of any worth going after. Lakes and streams of northern New Jersey, properly conserved and distributed where needed, will give an abundant supply for all community requirements, but full coöperation only, will secure that happy result.

Just prior to the World War, the water companies concerned in this paper, united in a plan to secure an abundant addition by taking water from the junction of the Raritan and Millstone Rivers, which was to be filtered (frequently being very muddy) and delivered in bulk to the different community distribution systems. They bought lands and prepared plans, but the War ended all possible financing. The succeeding great increase in construction costs, without authority to raise sales rates in proportion, prevented any subsequent practical steps for relief.

Meanwhile, summer shortage in supply caught all consumers, forcing curtailment of use and even hardship and community losses, for new industries were loath to settle where water might well be scarce. Many conferences were held between company representatives and locality committees and the type-setters reaped a harvest, but no final relief transpired.

There were three main proposals, viz.:

a. The companies would sell each distribution system to the locality served and with the proceeds, develop the Raritan-Millstone project and thereafter sell filtered water in bulk, for local resale to the citizenry, or,

b. Sell their plants *in toto* leaving the communities to organize one or more water districts and undertake self service, or,

c. Secure authority for such increase in rates as would make it possible to undertake large bonding for new construction.

A fourth scheme was broached, but was scarcely feasible,—viz., that the communities should finance the supply development, under company auspices and subsequent operation.

Much time was lost in these many-sided schemes and the serious drought of 1921 brought acuteness to the situation. For years, Elizabeth had been restive and desired to go alone (as it is now taking steps to do). Plainfield cared little for its neighbors and had for years felt aggrieved that water derived within its area had been furnished to other places, to its own detriment; in fact, it actually has drilled a couple of test wells as a start towards its own system. Naturally with the two larger places either against or luke warm in the consolidated plan, it could only fail. Westfield also started upon a well drilling course.

In 1913 the City of Plainfield went so far as to attack the validity of the organic union of the Plainfield Water Supply and Union Water Companies, hoping, if it could be dissolved, to proceed then to condemn the Netherwood plant and the Plainfield distribution system for its sole city use. The court did not agree and the appeal has never been prosecuted, consequently condemnation was not available.

A very good lawyer has given opinion that in his judgment the union was illegal, but in view of public needs for the water in the larger district, not apparently now available from other sources, he doubted whether any court would risk saying so.

It is an inescapable fact that these various communities have really a united interest, only to be served to advantage by a large private corporation or a well handled public water district commission. Each of the three larger companies applied to the Public Utilities Commission for higher rates, and with considerable justice in their pleas of greatly increased operating costs and larger value of plants in service. Some increase was accorded, but the companies have claimed it was still insufficient to enable new financing for betterments. The Commission took the ground that, when in receipt of generous earnings, the companies had distributed them to stockholders and had put in extended distribution systems to secure more business, but without provision for increased supply and better service to existing patrons. They were therefore not entitled to full relief until they changed that condition.

The Plainfield-Union Water Company has recently appealed to the Federal Court as against rate-rulings of the Commission.

In 1925 the City of Plainfield, still with hopes for more water,

appealed to the State Attorney General for legal relief. The State responded in an action in the Circuit Court in form rarely availed of for such a purpose, viz., "Quo Warranto" proceedings against the Plainfield-Union Water Company, requiring it to show cause why its original charter should not be forfeited; charging wilful violation of duty in not supplying water in abundance for all needs of the population within the original charter area of the Plainfield Water Supply Company. In the latter part of the year the case was tried with an unusual array of counsel, engineers, accountants, city officials, bankers and other lay witnesses, taking about two weeks time of court and jury. The case was based upon points heretofore noted in this paper, with evidence presented that on certain days, various properties and institutions in Plainfield had been deprived either wholly or in part of needed water; that manufacturing plants of great value to the city had had to drive wells of their own because the water company could not supply the demand; that the company's efforts had been to increase the number of consumers, instead of meeting the requirements of those already connected with its mains; and that outside of the abortive Raritan-Millstone project, no steps had been taken to further develop local sources. It was shown that success would have been likely had more wells been drilled and electrically operated as units; at some distance from the Netherwood plant, yet still within the Plainfield area. Further background was provided and used for what it was worth, by both plaintiff and defendant, that very short rainfalls had ruled in 1921 and 1923, not made up by the greater precipitation in 1922, entailing great shortage of supply throughout the whole district. The Plaintiff argued that the company should and could have taken steps looking to emergency relief, without entailing any prohibitive capital outlay.

The defendent contested very vigorously that no wilful neglect had existed or been shown; that it had done all that it was financially able to do under all the conditions; that no more water could be secured locally or at least in worth while quantities, and that, without large increase in rates, no further financing could be accomplished; that, granted excellent earnings in past years, no excessive distributions had ever been made; that such surplus as had been reinvested in pipe lines was fully justified by anticipated future business and that under present conditions stockholders would not contribute moneys for betterments nor could they be compelled to do so.

The case was really rather too technical for a jury. Still it gave

very close attention to the evidence, heard excellent closing arguments and a fair charge by the court. The deliberations were lengthy, but finally the verdict saved to the Company its charter.

As yet no appeal has been taken, so the status quo continues, viz.;

Regular increase in demand for water, without increase of supply in sight, until Elizabeth at least shall have carried out its program of self supply; after which the other communities may get relief, if not dried up from thirst in the meantime.

NOTES

Quo-Warranto-proceedings have been usually taken to prevent official usurpation of power.

A judgment rendered binds all parties because actions are brought by "the people."

Statutes permit such actions in many states but bar them in others.

Kansas—1883—Quo-Warranto will not lie where other legal remedies are adequate.

Alabama—1894—Capital City Water Company vs. State of Alabama. 105 Ala. 406–18 South 62–29 L. R. A. 743. "The fact that a city has, under an ordinance, contract with a water company chartered by the State, the right, on breach of the contract, to rescind the same, does not defeat the right which the State has, on an abuse by the corporation of its franchises, to annul its charter."

A forfeiture of corporate franchise can be enforced only by a direct proceeding by Quo-Warranto.

Georgia—1823—State vs. City of Savannah—R.M. Charlt 250.

Illinois—1844—Williams vs. Bank of Illinois—6 Ill. (1 Gilman) 667.

Illinois—1893—Citizens Horse Ry. Co. vs. City of Belleville—47 Ill. App. 388.

Indiana—1862—Little vs. Danville and W. L. Plank Rd. Co.—18 Ind. 86.

Pennsylvania—1841—Irvine vs. Lumberman's Bank—2 Watts and D. 190.

Virginia—1881—Pixley vs. Roanoke Gas Co.—75 Va. 320.

Pennsylvania—1905—Act. of June 14—1836 (P. L. 621) authorizing the maintenance of Quo-Warranto proceedings against a water company for supplying impure water, is not repealed or modified by Act of Apr. 29, 1874. 34 P. L. 93 providing a method of relief on complaint by an individual citizen.

Commonwealth vs. Potter County Water Company 61 A 1099 212 Pa. 403. The Company had, at low stage of a better supply, mixed impure pond water for use at fires and had an agreement with the borough for so doing, but in the proceeding nevertheless lost its charter.

DISCUSSION

C. C. Vermeule:[2] Mr. Tribus has set forth in an acceptable manner conditions out of which some of the litigation concerning the Plain-

[2] Consulting Engineer, New York, N. Y.

field-Union Water Company has developed. In view of his connection with the case it is necessary for the writer to make it clear that he has no authority to speak for any of the water companies, and is simply presenting his personal views as a citizen of New Jersey fully in touch with the subject.

The paper shows that the legal remedies at hand available to the several communities are adequate. The Quo Warranto to which he refers, and which was intended to deprive the Company of its charter, can in no way be considered an adequate remedy. It is by no means constructive, since it does not determine who shall ultimately own and operate the property, or provide any remedy whatever for present conditions. On the other hand it was destructive and introduced confusion.

The constructive remedies are those provided by law. Either the communities should take over by purchase or condemnation the water works, or they should be willing to allow to the water companies such rates as will enable them to finance future developments. Such developments they have had in hand for a long time and have expended a very considerable sum of money on some, but they have been unable to go further. Any practical method of financing requires that the revenue to provide for such financing shall not simply be hoped for but shall be in sight. So long as the companies are charged with the duty of providing for the needs of the community, it would seem as if it is their duty to adopt all possible means through litigation or otherwise to provide such revenue.

The situation is that the three companies are supplying a large number of municipalities through sources used in common. In general, according to returns of 1924, the total consumption of water amounted to 26,947,000 gallons daily. Of this 18,058,000 gallons came from driven wells, 6,458,000 gallons from surface water supplied by the companies and 2,431,000 gallons was purchased from outside sources. The district contains in large part a residential population, suburban in character, amounting in the aggregate to about 90,000 persons. The remaining 150,000 population, of which 135,000 is supplied by the Elizabethtown Water Company alone, is largely industrial in character, and the large industries within this district would naturally prefer surface water, softer in character than the well water. On the other hand, the residential portion of the district emphatically declares it is in favor of the well water. Even if the 18,000,000 gallons daily now taken from wells shall be materially

reduced and only the more desirable water used, it will be ample for the supply of this portion of the community for many years to come. Notwithstanding much that has been written on this subject, it is the writer's experience that residential communities are much in favor of well water even though it may be somewhat harder, for it has had marked compensating advantages for their use.

This being the state of affairs, we will turn for a moment to the surface supplies available. Many years ago the water companies obtained the right to take 20,000,000 gallons daily from the Raritan River, this water to be filtered. Raritan River water has been used for many years at Somerville and Raritan after filtration through mechanical filters and has been found very acceptable. Should the companies be permitted to carry this plan into effect, introducing this water into the industrial parts of the district and re-arranging their supplies so that the well waters could be used in the residential portions, immediate relief would be had. The larger part of the supply main necessary for this purpose has already been laid and the pumping station and plant could be quickly constructed.

However, if this plan is not acceptable, the whole district would be relieved should the City of Elizabeth alone take over the distributing system and introduce this supply.

There can be no question that the general plan of supplying this group of communities from a single source through private water companies is the most economical of all plans proposed.

The alternative plan above mentioned is next in rank. While there has been considerable agitation for public ownership, the economy of the present method is apparently appreciated by a large part of the community, consisting of persons best qualified to pass judgment upon it. Furthermore, whenever a move for public ownership has approached the point where the municipalities must immediately face the expenditure of money necessary to carry it into effect there has been hesitation to such an extent that one is left to infer that possibly a much larger part of the community than is apparent really prefers the present method of supply.

There have been various plans urged for introduction of a supply through the State Commission. The difficulty of all of the plans thus proposed is that they call for an unduly large capital outlay in the immediate future, whereas the plan which has been offered by the company provides for immediate necessities at a much smaller cost and is capable of expansion as needed.

There have been certain other difficulties in the way of this plan of a comprehensive supply, and these are inherent in the form of government. This form of government is one which has been preferred by the people of New Jersey and exists at their instance. I cannot state the situation as to this any better than it was stated by Governor Moore in a communication to the Legislature last June, which I here quote.

Even the State Commissions thus far created have no power to construct water works or to purchase property except at the instance of two or more municipalities, and with funds provided by the same. No attempt to compel municipal governments to coöperate with or submit to assessment by such State Commissions, has been attempted. The home rule spirit has prevailed in all our legislation.

Our State Commissions and their legal and technical staff have naturally felt that their work could go forward more in accordance with their ideas, and faster, if less power rested with the municipalities. Broadly only two methods of accomplishing this have been proposed. The first is creation of an extra municipal authority over a group of contiguous municipalities with power to tax; and secondly direct financing by the State, with the intent, however, to ultimately assess the cost upon the municipalities. The second plan is naturally more acceptable to such municipalities as have thus far failed to provide themselves with an adequate supply of water. Nevertheless it is not evident that the demand comes from them for present action of this kind.

The writer has never regarded the water situation in New Jersey as in any sense difficult from an engineering point of view. Such difficulties as there may be are inherent in the form of government preferred by the people, except as they may be psychological.

QUALITY OF WATER AND INDUSTRIAL DEVELOPMENT[1]

By W. D. Collins[2]

Manufacturing in the United States had its early development in the northeastern part of the country. The movement of the center of population toward the west has been accompanied by a similar movement of industrial development. Although the quality of the natural waters was not a large factor in determining the location of the first manufacturing establishments in this country, it happened that nearly all these plants were able to obtain abundant supplies of clear, soft water.

In 1849 the industrial activity in the States of Ohio, Indiana, Illinois and Michigan, as measured by the value added to raw materials by the process of manufacture, was only 11.1 per cent of the total for the United States. New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, and New York together had 47.7 per cent of the total. In the first group of states the water supplies range from moderately to very hard; in the second group nearly all the waters used by industrial plants are decidedly soft. In 1919 the industrial activity in the group of states with hard water was 55 times as great as in 1849 and amounted to 25.5 per cent of the total for the United States. In the states having soft water the activity was only 13 times as great as in 1849 and only 27.8 per cent of the total for the United States. The apparent movement of industrial activity toward the hard-water regions has been brought about more by the development of new industries and plants than by removal of plants from one place to another.

Certain industries have had their greatest growth during the last fifty or sixty years in the places where they were first established. The iron and steel industry, for example, has grown in Pennsylvania

[1] Published by permission of the Director, United States Geological Survey. Presented before the Chicago Convention, June 7, 1927. Based on data in United States Geological Water-Supply Papers 496 and 559, which are now out of print, but are available for consultation in many libraries.

[2] Chemist in Charge, Quality of Water Division, United States Geological Survey, Washington, D. C.

and Ohio so steadily that even though large plants have been established in other states, these two states had 66 per cent of the total business for the United States in 1919. Quality of water is an almost negligible factor in the location of iron and steel mills. The manufacturing of wool and silk goods, on the other hand, has been confined largely to a few states that have generally excellent water supplies. Cotton manufactures were formerly confined to New England. The recent development of the industry in the South is taking place where soft water is available.

The manufacture of food products has developed generally throughout the United States with more relation to population than to any other factor. The location of plants in this industry has been affected only secondarily by the quality of water available.

Every manufacturing establishment uses some power. If the use is small, it is often cheapest to buy electric power and avoid trouble about water supply for a power plant. If much power is required, and especially if steam is to be used in a manufacturing process, as in the manufacture of water gas, the quality of water available is of great importance. Years ago the general conception of a water analysis was a set of figures which in some way indicated whether or not the water was safe to drink. At most these analyses may have given figures for the total hardness as an indication of the industrial value of the waters. About twenty-five years ago the United States Geological Survey began systematic studies of the chemical character of natural waters with reference to their industrial use. The most comprehensive studies on river waters were made about twenty years ago, and the analyses made then are still the most useful information available as to the chemical character of some public water supplies. The recently formed Committee 19 of this Association is now aggressively attacking the problem of proper water supplies for boiler feed and will direct more attention to the industrial utility of waters from public supplies.

Accurate knowledge of the chemical character of the water furnished by any public supply system is necessary for the most effective operation of the plants that use the water and is also necessary to persons or companies who are considering places for the location of a new plant. The operators of the waterworks can get this information for everyone to use at much less total cost than is involved in attempts by a number of different agencies to obtain it. If the

composition of the water varies from week to week the individual cannot learn all he should know about it from a single analysis.

Practically all public water supplies are now safe to drink. There is vast room for improvement of water supplies with reference to industrial use, through better knowledge of the composition of the water, better treatment to make it suitable for industrial use, and better control of the treatment to insure uniformity of quality.

PUBLIC RELATIONS[1]

By Daniel T. Pierce[2]

It will help clarify the subject of this paper if we begin with a premise nobody will probably contradict, namely, that the relations between a utility company and its consumers and customers, between a manufacturer and his "trade," between shippers and travelers and transportation agencies, are truly satisfactory only when there is general confidence that the service rendered is all that can be reasonably expected, that the price charged for it gives a reasonable but not exorbitant profit, and that the management is continually alert to effect improvements in the service.

The purpose of public relations work is to establish such confidence. The confidence must be deserved before public relations work can be successful. Those who have engaged long in such activities know they cannot possibly succeed unless they are based on truth, frankness and good performance. Such specialists will refuse to be connected with anything that lacks such a foundation. Unfortunately, however, there is a great deal of publicity and propaganda being carried on which is so often misunderstood as being public relations work that it will be helpful to trace the development of the latter.

Some three hundred years ago, if a person wished to mould public thought, he wrote or caused to be written a pamphlet setting forth his views. Many of these pamphlets are highly prized by book collectors now and thousands of dollars are spent at book auctions for tracts that were sold for a penny when published. What may be called newspapers were then just beginning to appear, but they were without influence until press censorship was abolished in England in 1698, and then they became party organs. The same is generally true of the early newspapers in this country. During this long period the pamphlet was the chief method of advocating reforms and new ideas.

This method of delivering a message to the public is very poor

[1] Presented at the Chicago Convention, June 8, 1927.

[2] Public Relations Counsel, 120 Broadway, New York, N. Y.

unless coupled with means for assuring that the message actually reaches those for whom it is intended. It was used so long because no substitute was to be had, and the pamphlets were mainly about political affairs or religious questions, the two topics in which men able to read were most interested in those days. A much larger proportion of those able to read were eager to buy such tracts a century or more ago than now, because today the same information is furnished to them in other ways without cost.

When newspapers actually became what we would recognize today as newspapers, between 75 and 100 years ago, and persons began to turn to them for something beside political arguments and religious discussions, their usefulness as carriers of messages about all sorts of things was quickly recognized. Persons burning with zeal for this, that or the other cause tried to get newspaper publishers to print contributions on these topics in which individuals were so much interested. They were only successful, however, as a rule, when they could pay the newspaper proprietor for the privilege of appearing in print.

Now, there was nothing venal about this for two very good reasons. The income of newspapers in those days was very small and most of the articles sent to their proprietors were of very limited interest. The proprietor had to spend his meagre income for what would interest the largest number of readers or be paid for departing from this self-evident rule. This condition did not change much until receipts from advertising increased materially.

With the enlarged income from advertising came the press agent. He distributed advertisements to the publishers of newspapers and at the same time demanded write-ups from them. As his position became more firmly established he demanded more write-ups and developed into a pest we still have with us.

That was not the worst he did, however, for his success in getting crude write-ups printed led him to develop whatever talent he had for authorship, and he produced many quite interesting stories about the persons who employed him or about the goods they had to sell. For a time the hardworking reporters and city editors were glad to get these interesting articles, but they gradually learned that the truth rarely lay in them. When the newspapers realized how very little their readers cared for such interesting but unreliable stories, the press agent lost standing in newspaper circles. There are many of them today, but they have to work very hard and use much more intelligence to get anything printed now than fifteen years ago.

The better men among press agents were glad to give up the spreading of mendacious though interesting stories about actors, politicians, social aspirants and the like as soon as something better offered an outlet for their talents. This opportunity was afforded by publicity work. Its history is interesting. A good many years ago protests against railroads began to increase rapidly. At first railroad men made no reply to them generally. When a reporter succeeded in reaching such an official he was told that there was nothing in such protests so far as that official's line was concerned. Then legislatures began to investigate and afterward to act. Congressmen began to see that real interest was felt in railroad management and policies by influential sections of the public, so they became busy. There were real abuses to be corrected, we all know now, but in those days politics added a mass of fictitious abuses to the real ones, thus producing many indictments against railroad management that still influence public thought to some extent

When the railroads came to a realization of what threatened them, they turned to publicity for help. Some of the indictments against them were easily answered by facts and statistics. Others required explanations of the logical reasons for practices in rate making, such as an explanation of why it was equitable and fair to charge more per hundred pounds for transporting sewing machines than coal over the same distance. And there were other indictments that were so justified that for a time the railway attitude was to keep quiet about them and give lawyers time for study and thought, for the old-school railway managers were very loth to become wholly "good" and proposed to hang on to some practices they had adopted just so long as they could. This was an ideal time for publicity, for giving out nothing but facts about some things, for saying nothing about other things where the facts, if known, might be damaging, and for pointing out errors in facts and logic made in statements by persons attacking the railroads. The issues were too serious to justify giving out untrue information; this is the practical difference between press agent work, which has little regard for the truth, and publicity work, which is based on the literal truth of everything said.

Some of the leaders of railroad affairs soon went a step further, when they decided that the public would never be satisfied and legislators would never let up attacking the roads unless the whole truth were told. They realized it would be years before the public believed them, but they knew the railroads would be running long after

the managers of that day were dead and could be operated by their successors more satisfactorily to everybody if they could regain the confidence of the public. It was then that the public relations counsel proved the value of his services. He was largely influential in persuading railroad owners to realize that they had just as clear a responsibility to the public which granted them franchises to build and operate their lines as to their stockholders who owned the lines and to the bondholders who loaned them money. And he knew where, and how, and when to tell the public everything it had any justification for asking about railroads. That he did and is still doing, and you can see the result in the general confidence in our railroad managements today.

While the steam railroads were passing through their long period of tribulation, the state public utility commissions had been giving attention also to electric railways with the result that they have had a very hard time. There had been many consolidations of small companies into large ones, on the correct theory that a large system can be operated to give better service at a lower cost than many little ones can. But in the consolidation it was necessary to take over many small and often obsolete plants and rolling stock that was poor and inadequate. Large sums of money were needed to provide new equipment, and this money could be obtained only by bond issues as a rule. But electric railway bonds were hard to sell because the utility commissions were reluctant to authorize rate increases to pay the interest on these bonds. Neither the commissions nor the public could appreciate that for the increased fare longer rides in better cars run more frequently than before would be possible. Labor difficulties became frequent; some of the strikes were very serious. Public relations work under such conditions was complicated, multifarious and difficult, but it was making headway slowly until the motor bus arrived on the scene. It introduced so many complications in the local transportation situation that the reorganization of the whole business was necessary. It is going on now, public confidence in the desire of many street railway companies to give good service at reasonable rates is returning, but electric railway companies still face many serious problems.

When we turn to electric lighting companies we see a more pleasant picture. The companies have always been owned to a considerable extent by persons living in the communities they served. They were largely business men and bankers sensitive to local public

opinion; speaking generally, they wished good public relations and they wished enthusiastic employees. They proved this long ago by advocating customer ownership and employee ownership of stock. Their readiness to adopt every new improvement that would keep down the cost of producing current is unnecessary to dwell on. Their desire to make every contact of the public with their employees and with their offices a pleasant one is evident everywhere.

In spite of this record of achievement in public relations work, some of them are going through now one of those episodes which could have been avoided had they appreciated that it is just as important to extend the basic principles of such work into the field of finance as to apply them at home to their relations with their customers. You will recall that some years ago there was a considerable discussion by engineers and by the non-technical public about super-power schemes for tying together steam and hydro-electric stations so as to utilize to the best advantage all the power resources of large districts. Its advantage is that what would be overloads on some stations can be carried by underloaded plants elsewhere in a district.

This superpower feature of electric supply has been carefully studied by the men administering the affairs of many electric companies. It will involve large sums because the transmission lines connecting the power stations cost, roughly, about as much as the stations. Accordingly there was developed the holding company to get together the companies which should be assembled into the superpower system for a district and to provide the funds for the transmission lines and all other items of expense which should not be charged to any one local company but were properly chargeable to the superpower system as a whole. This was a matter of financial administration and understood by financiers concerned with utilities; there has been no secrecy about it. But there has been a good deal of secrecy about the grouping of some local companies into one or another superpower system. Rival interests have been trying to acquire a considerable number of local companies for their respective superpower aggregations. Until the purchases are made every effort is naturally made to keep the negotiations under cover; that is ordinary business prudence and established business custom.

Yet because no general attempt was made to tell the public what is involved in carrying to realization these superpower projects which have a general endorsement by the public, the holding company, the only agency that can apparently be used to finance and administer

such desirable projects, is now being held up by some well-known men as a potential danger. The situation is really amusing, because the men who are organizing these holding companies are as strong believers and practicers of public relations work as we have in the country, and the charges of secret skullduggery brought against them have surprised them greatly.

We have now taken a glimpse at what the railroads, the electric railways and the electric light and power utilities have accomplished by public relations work, and it is time to consider your own problems as water works men. According to your Association's "Manual" there are about 3000 privately owned and 7000 municipal water works in the country. Municipal works, being more or less under political control, will naturally utilize publicity methods of improving their position with the public, foi it is rare that politics permits complete frankness.

Men interested in water companies do not need to be reminded that some thirty years ago disastrous financial experiences shook public confidence in such companies seriously. Then came a long period of vociferous demand for public ownership, coupled in many cases with protracted difficulties while public utility commissions were learning enough of the details of water supply to be reasonable in fixing water rates. It was a hard task to earn enough money to pay operating expenses and interest on bonds and the stockholders had a lean time. In the last few years conditions have improved greatly. Courts have cleared away many disputed questions which utility commissions could not settle finally. Water company securities are now readily absorbed and we are seeing many companies taken over by holding companies, a step that will be beneficial to the consumers served if these holding companies are wisely administered, as they presumably will be.

Under these new conditions it is desirable for water companies to begin public relations work, especially where the rates are now too low. It is distinctly short-sighted for companies and ultimately disastrous for consumers to let the idea persist without contradiction that a company need not be paid enough to earn a reasonable profit. When the consumers are awakened to the truth, as they must be eventually, they will have a legitimate grievance against the company that has withheld the facts. There are some persons so constituted that it is very hard for them to be fair, but American men and women, in the mass, are honest, fair and shrewd, and will act justly when satisfied

they are being treated equitably and efficiently. Consequently a considerable part of public relations work must be done by appeal to masses.

This brings us to some of the principles on which any sound and successful public relations effort must be based. Nearly all corporation officials go astray because they insist upon treating discussions with masses of people on the basis of logic, statistics and what they are pleased to term "the facts." We all know, however, that one may have all the statistics and facts on his side, and yet not be able to convince anybody. People in the mass are not moved by statistics. They are moved by actions and attitudes, plus facts which appeal to their imaginations and create confidence and belief.

This is not to say that the facts can be ignored. Facts are absolutely essential and this is a good place to say that no publicity campaign can achieve success that is not founded on honesty and a good cause. Very often it is found that the organization contemplating a public relations campaign looks upon it as an umbrella or screen under and behind which it can do as it pleases. Publicity obviously is a two-edged sword. Don't take it up unless the cause is just and capable of honest defense.

Another don't. Don't expect to hire a public relations counsel or even a publicity man, put him in a corner, leave him out of your councils and expect him to accomplish anything. If this kind of effort is worth taking seriously it is worth all or a large part of the time of a very high-class man who is in close touch with everything that is going on currently, everything that is planned for the future, every major problem of the company he is working for. Tell him everything and let him decide how the company and its acts should be interpreted to the public.

It is very important, also, that communications to the public should be based on an act rather than merely a profession or an editorial deliverance or argument. For example, it is all very well for a railroad to say that it is human and considerate. But if a railroad, as one of them did not long ago, slowed up all its trains passing a house where an obscure individual was very ill, in order that he might not be disturbed, that is a fact from which anyone can be allowed to draw his own conclusion, and those conclusions will be far more positive than could be set up by any amount of assertion.

As to methods, if one wishes to broadcast an idea, there is nothing better than the advertising pages of local newspapers. Nothing, in

fact, anywhere near as effective. There are occasions, of course, when a matter cannot be covered in one advertisement, or, perhaps, not in the most effective way as in series of advertisements. That is where the pamphlet comes in. And pamphlets are made much more effective if they are distributed with a letter to the key men of the community with the request that the company's statement be given consideration and the facts it sets forth weighed before any opinion is formed. Very often it is necessary to get small groups of individual critics together and talk to them. They are flattered that this trouble is taken to convince them. Furthermore, talks of this kind give an opportunity for give and take and the answering of mental reservations which will otherwise not be brought out.

There is another kind of public relations effort that is represented by so simple a matter as keeping equipment, employees and plant neat and attractive. This has a tremendous effect in persuading the public that the company is anxious to do things properly. Shabby-looking equipment and personnel make just the same effect on the customer of a utility that a gloomy, dusty store and frowsy clerks make on you when you enter such a place.

Contact with newspaper men is something about which it is difficult to generalize; however, there are one or two rules that may be mentioned. The first is to trust them. Don't try to jam a lot of publicity down their throats. Make them welcome. Tell them about things in advance. Educate them before a rate increase is to be asked. Satisfy them before things get into the atmosphere of contention and agitation when it is practically impossible to secure a judicial consideration of any matter. That is where most of the trouble comes in with utilities, as every public relations man knows. He is rarely sent for until the house is on fire and then he is expected to perform some overnight miracle which is impossible.

Another most important factor in the establishment of good public relations consists, not in the declaration of benevolent intentions or worthy purposes, but in activities that show a real interest and concern over the consumers' welfare. Tell what things are actually done to improve service; what investigations are made; what exchange of information to assist this work goes on among similar companies. Water works men, I assume, are studying all the time to improve their service, which means safe-guarding the health and welfare of millions of people. Personally, I have never seen anything printed on the subject; a statement which indicates I do not read your

"Journal." How many persons in any of the cities from which you come will ever read it? Every new piece of equipment or extension of importance should be talked about in papers that are read; the good relations with newspaper men, previously mentioned, will bring this about.

You will realize, I am sure, how difficult it is even to outline a subject such as this, because anyone who for twenty-odd years has been dealing with public relations problems knows that no two of them are alike except as to some of the general principles that have been mentioned, and in one other respect, namely, that effort of this kind must be continuous. Don't fool yourselves by thinking that the publication of a few advertisements and the distribution of a few pamphlets have reached everybody and convinced everybody. You are looking for every little item that concerns you and you are likely to assume that because you have seen it everybody else has seen it.

They haven't. You may be sure of that. The only really consistent piece of public relations work that has ever been done is that of the Bell telephone organization. In season and out, fair weather and foul, good times and bad, they have talked about their service, explained its ramifications, why they need so much capital, why they need the rates they charge, and what is the result? Today they can probably sell more common stock at a higher price than any other industry in the country. No more impressive proof can be given of the effectiveness of good publicity continously applied.

John M. Goodell

Born August 3, 1867
Died June 21, 1927

Mr. Goodell became a member of the American Water Works Association on April 27, 1894, and was the editor of its JOURNAL from 1917–1921. For some years he was a member of its Publication Committee and the secretary of its Committee on Standard Form of Contract. He had much to do with the establishment in 1920 of the Standardization Council and from its beginnings he was one of its most wise and constant advisors.

In the passing of Mr. Goodell the American Water Works Association loses a member who was among the best informed as to its history and growth and who persistently and effectively worked in a quiet way for a long term of years to bring about its development in size, strength and usefulness. In his death the Association loses a helpful and powerful influence which he exerted so modestly and cautiously that comparatively few members knew about the time and strength which he devoted so advantageously to the advancement of the Association.

Mr. Goodell was born in Worcester, Massachusetts, and was graduated from the Worcester Polytechnic Institute in 1888 with the degree of Bachelor of Science in Civil Engineering. During the next two years he studied engineering at the Polytechnic Institute at Zurich, Switzerland. He then joined the editorial staff of *Engineering News* for two years and next was an associate editor for two years of *Engineering Record* after which for three years he was assistant secretary of the American Society of Civil Engineers.

From 1897 to 1902 he was associate editor of *Engineering Record* following which he spent a year on paper mill construction as a member of the staff of Joseph H. Wallace at Sault Ste. Marie. In 1891 he published a translation from the German of Baumeister's

book on *The Cleaning and Sewerage of Cities*, and in 1899 another book on *Water-Works for Small Cities and Towns*. From 1903 until 1912 Mr. Goodell was editor-in-chief of *Engineering Record.*

Later Mr. Goodell was engaged on editing work for Metcalf & Eddy on their three volumes on *American Sewerage Practice*, and he also was occupied with the reorganization of the American Concrete Institute as well as with the development of the American Highway Association.

Beginning in 1917 Mr. Goodell resided for two or three years in Washington where he was connected with publicity work for several activities, most of which were related to the war. He was employment manager first for the production division and later for the entire Emergency Fleet Corporation. During the latter part of the war he was acting chairman of the National Highway Council and later was consulting engineer to the Bureau of Public Roads, chiefly on its plans for organization and publicity.

After the war Mr. Goodell returned to New York to reside and became actively engaged in editing work chiefly as related to publicity and advertising and to the preparation of concise summaries of technical reports for the use of business establishments. He also did important work of a statistical nature for several large companies. One of his principal clients was the Babcock and Wilcox Company.

In spite of the very active part which Mr. Goodell played at Washington during the war he consented in 1917 to become editor of the JOURNAL OF THE AMERICAN WATER WORKS ASSOCIATION and continued his efficient work, particularly in getting out papers of short and moderate size of practical benefit to the water works industry. He resigned as editor in 1921 to assist Metcalf & Eddy in condensing their three volumes on *American Sewerage Practice* into the so-called 500-page "Textbook" for use in colleges. After 1921 the efforts of Mr. Goodell to advance the standing of the Association continued unabatedly, particularly with respect to the activities of the Publication Committee and plans for the preparation and publishing of the *Manual of Water Works Practice*, the quality of which in many particulars is a splendid testimonial to the ripe experience and foresightedness of its former editor.

Mr. Goodell was not in robust health during the later years of his life, but continued with characteristic energy and persistence to carry on during long hours, contrary to the advice of his physician.

He remained at his desk until June 18, when he complained of feeling badly and was taken to the French Hospital in New York. Shortly afterward he suffered a stroke, had another on June 19 and a third on June 21 which caused his death.

He is survived by his widow, Mrs. Letha L. Goodell; a son, John Boyden Goodell, who resides in New York; a married daughter who resides in Oakland, California, Mrs. Dorothy Goodell Remsen; and a younger daughter, a student at Vassar College, Miss Barbara Letha Goodell.

George W. Fuller.

Charles Randolph Wood

Died June 8, 1927

The death of Charles R. Wood, which occurred so suddenly during the convention of the American Water Works Association, was not only a great shock and a tragedy to all those in attendance at the annual meeting in Chicago, but also spread great sorrow among the members at large as it became known through the public press and our technical publications.

He had seemed especially interested in this convention and, for many months preceding it had taken every opportunity to predict its great success and encourage a large attendance.

At the convention itself for the few days we were privileged to have him with us, he was particularly eager to assist, not only in the way of entertainment in which, as always, he was so kindly and so generous, but also in the many other activities of the Association. Probably the last signature he wrote was affixed late on Wednesday morning, June 8, to a report of the Convention Committee of which he was a member, and his last official act for the Association came just before noon on that same Wednesday, when at a meeting of the Nominating Committee, he made a motion that the vote on the selected nominees be made unanimous.

On the adjournment of this meeting he walked from the committee room down the adjoining hallway and spent some moments talking with a number of his friends; but having doubtless some premonition of the coming attack he went, when the opportunity came, into one of the small conference rooms to rest for a moment and then started, unfortunately alone, to go to his own room. Before he was able, however, to reach the entrance of the elevator his strength gave out and he was assisted by hotel attendants through a strange coincidence, into the same room in which, but a short time before, his Convention Committee had been meeting.

The house physicians were immediately called and did the little that could be done for this attack which was pronounced acute dilation of the heart. Before he lost consciousness, the doctors asked him if he had any friends in the hotel, and his reply was characteristic, "Yes, I think I have lots of friends, but don't bother them." Not long after, the end came.

While Charles R. Wood's firm held an Associate Membership in this organization, he himself was an Active Member and ever took a great deal of pride in the American Water Works Association. He was always intensely interested in its success—not passively or intermittently. Our Executive Committee and the Secretary's office continually sought and welcomed his counsel and suggestions.

In this Association no single member had more friends or a wider acquaintance. He had never held an office in our Association, but his position in our affections was very high, and is secure. The place made vacant by his death will be very difficult to fill.

BEEKMAN C. LITTLE.

RESOLUTION OF AMERICAN WATER WORKS ASSOCIATION ON DEATH OF CHARLES RANDOLPH WOOD

WHEREAS, the late Charles R. Wood departed this life the 8th day of June, 1927, at the Hotel Sherman, in the city of Chicago, and during the Forty-seventh Annual Convention of the American Water Works Association, in which he was taking an active interest, and

WHEREAS, the deceased has for many years been an active and stimulating influence in the councils of our Association, having given of his best to the advancement of its interests, and

WHEREAS, we, members of this Association will miss his counsel and advice in our circle, and his friendship and good fellowship in our social relations;

Therefore Be It Resolved, that we, the members of the American Water Works Association, in session at our annual meeting in the Hotel Sherman, Chicago, Illinois, June 9th, 1927, regret his untimely demise and hereby register this expression of our loss, and it is

Ordered that this *Resolution* be spread upon the minutes of this meeting, and that a copy of these *Resolutions* be embossed and forwarded to our deceased member's family.

ABSTRACTS OF WATER WORKS LITERATURE

FRANK HANNAN

Key: American Journal of Public Health, **12**: 1, 16, January, 1922. The figure 12 refers to the volume, 1 to the number of the issue, and 16 to the page of the Journal.

Tensile Properties of Soldered Joints Under Prolonged Stress. J. R. FREEMAN, Jr., and G. W. QUICK. Metal Ind. (New York), **24**: 7–10, 1926. From Chem. Abst., **20**: 1212, April 20, 1926. Tensile tests of lead, tin, and 50–50 solder were made by applying definite stresses to wires 6 inches long and 0.1 in. in diameter, and measuring the elongation with time up to 28 days. Lead was found to support stress of 415 pounds per square inch without failure. Tin showed constantly increasing elongation under stresses greater than 230 pounds per square inch, and solder gave same result under stresses above 70 pounds. Test specimens of soldered joints were lap-joints of galvanized iron and sheet-brass. Apparatus for securing constant temperature and pressure in making specimens described and illustrated. No creep was observed in any soldered-joint specimen at shearing stresses up to 400 pounds per square inch. No specimen jointed with tin failed at this stress. Joints made with solder showed failures at 400, but not at 200 pounds per square inch. The 50–50 solder failed before 60–40 (lead-tin respectively), and galvanized iron joints failed before brass joints.—*R. E. Thompson.*

Prevention of Scale and Rust. DE GRAHL. Gesundh. Ing., **49**: 45–6, 1926. From Chem. Abst., **20**: 1291, April 20, 1926. Precipitation of normal carbonates is prevented by addition of a soluble chloride to the water, sufficient being added to change part of calcium content to calcium chloride. Method recommended for household installations.—*R. E. Thompson.*

The Behaviour of Iron, Bronze, and Brass in Solutions of the Salts and Salt Mixtures Contained in Waste Liquors from the Potash Manufacture at Ordinary Temperature and at Temperatures and Pressures Prevailing in Steam Boilers. O. BAUER, O. VOGEL, and K. ZEPF. Mitt. Materialprüfungsamt Kaiser Wilhelm Inst. Metallforschung, 1925, No. 1, 62 pp. Chem. Abst., **20**: 1211, April 20, 1926. Systematic determination of iron, bronze, and brass corrosion in resting and moving solutions of magnesium chloride and sulfate, sodium chloride and sulfate, calcium chloride, and various mixtures of these, in potash liquors, in river waters, and in distilled water. Tables given including data for salt concentrations used and corrosion results over period of 30 days. Following are conclusions drawn. Bronze and brass are only slightly attacked by the salts and waters. Magnesium salts at ordinary temperature in con-

centration corresponding to 112–9 German degrees of hardness are not dangerous to iron. Magnesium salts in feed water to steam boiler must be regarded as dangerous, increasingly so with concentration. Explanation of this is given in hydrolytic decomposition of magnesium salts at high temperature and pressure, producing effect of acid.—*R. E. Thompson.*

The Action of Dyes Used in Paper Making on the Animal life of Streams. O. Haempel. Z. Nahr. Genussm., **50**: 423–6, 1925; cf. C. A. **6**: 784. From Chem. Abst., **20**: 1291, April 20, 1926. Effect of various dyes on fish and other lower water animals was determined.—*R. E. Thompson.*

Separating Scale-Forming Ingredients from Boiler Feed-Water by Preheating and Sedimentation. O. Gunther. U. S. 1,579,444, April 6. From Chem. Abst., **20**: 1679, May 20, 1926. Mechanical features.—*R. E. Thompson.*

Action of "Hot Wall"; a Factor of Fundamental Influence on the Rapid Corrosion of Water Tubes and Related to the Segregation in Hot Metals. C. Benedicks. Trans. Am. Inst. Min. Met. Eng., February, 1925 (advance copy), 30 pp. From Chem. Abst., **20**: 1211, April 20, 1926. Although it is known that dissolved air in water has a serious corrosive effect on water tubes, it is not conceded that gradual liberation of air from water or presence of entangled air can account for localized corrosion of, e.g., boiler tubes, and to account for this a condition designated as "hot wall" is introduced. Hot wall is a condition converse to that produced by permitting gas containing vapor to come in contact with cold object on which part of vapor will be condensed if plate is below dew point. Thus if a liquid (water) containing a gas (air) comes in contact with hot plate, a new gaseous phase is produced and bubbles of gas separate on plate. This is supposed to occur in boiler tubes, and the gas bubble being non-conductive causes hot spot on tube, and any chemically corrosive action which may be proceeding more or less slowly will be accelerated by rise in temperature. This view may explain localized corrosion which occurs when different metals are used in construction. Remedy is to remove dissolved air prior to contact with metal tubes. Action of hot wall is special case only of spontaneous concentration differences that may occur in primarily homogeneous solution when subjected to locally different temperatures (Ludwig-Soret action).—*R. E. Thompson.*

Chemical Relation of Salt Dome Waters. H. E. Minor. Bull. Am. Assoc. Petroleum Geol., **9**: 38–41, 1925. From Chem. Abst., **20**: 1290, April 20, 1926. Chlorine content of ground waters from Texas and Louisiana salt domes has been found useful in identifying source of waters and in correlation of water-bearing sands. Amount of chlorine is lowest in near-surface water and increases downward, reaching saturation near salt of shallow cores; but in domes of deep-seated type rising gradually at rather uniform rate below 2000-foot level.—*R. E. Thompson.*

Determination of Chloride in Water. H. W. Van Urk. Z. anal. Chem., **67**: 281–8, 1925. From Chem. Abst., **20**: 1290, April 20, 1926. Mohr's titration

method is discussed critically on basis of mass-action law and as result of mathematical study certain improvements in technic are suggested. The concentration of chromate should lie between 0.7 and 1.5 millimoles per liter. The pH value of water titrated should be between 7 and 11. If water is alkaline to tropeolin 0 or acid to rosolic acid, it should be neutralized. Most suitable pH is 9, at which point phenolphthalein is barely pink. Magnesium oxide is unsuitable as neutralizing agent but sodium bicarbonate is advantageous. Water saturated with magnesium hydroxide has pH value of about 11.—*R. E. Thompson.*

Comparative Study of the Oxidation Number of Water by the Kubel-Tiemann Test and of Its Chlorination Number. Karl Keiser. Gas u. Wasserfach, **69**: 42–3, 65–9, 1926. From Chem. Abst., **20**: 1290, April 20, 1926. Determination of organic matter in water free from albuminous decomposition products may be made by potassium permanganate oxidation (Kubel method) or by chlorination (Froboese method); but if water is contaminated with sewage, the chlorination method must be used for exact results. Comparisons of the two methods are given for various types of contaminated waters in 15 tables. In certain cases chlorination of raw water increases filterability by influencing colloidal nature of its organic matter.—*R. E. Thompson.*

The Chemical Reaction of the Rusting of Iron. Joh. Scheiber. Farbe u. Lack, **31**: 11, 125, 1926. From Chem. Abst., **20**: 1585, May 20, 1926. Review of electrochemical theory of corrosion.—*R. E. Thompson.*

Calcium Chloride Waters from Certain Oil Fields in Ventura County, California. F. S. Hudson and N. L. Taliaferro. Bull. Am. Assoc. Petroleum Geol., **9**: 1071–88, 1925. From Chem. Abst., **20**: 1199, April 20, 1926.—*R. E. Thompson.*

Probable Origin of Thermal Waters of Aix-les-Bains, Savoy, and the Rôle of the Tectonic Accidents in the Thermalization and Mineralization of the Springs. W. Kilian. Soc. Geol. Belg. Livre jubilaire, 1874–1924, 97–102, 1925. From Chem. Abst., **20**: 1199, April 20, 1926. A geological study.—*R. E. Thompson.*

The Action of Water Containing Ammonia on Pipes and Boiler Plates. M. Tilgner. Chem. Ztg., **50**: 48, 1926. From Chem. Abst., **20**: 1211, April 20, 1926. Water containing 8–15 p.p.m. of ammonia showed strong corrosive action.—*R. E. Thompson.*

Public Swimming Pools. R. Messer. Virginia Municipal Review, **3**: 9, 341, September, 1926. Solution of public swimming pool problem involves rigid enforcement by local health department of minimum requirements for public health safety. These include a satisfactory source of water supply, a minimum replacement with new or re-purified water, and the provision of ample toilets and showers.—*G. C. Houser.*

Typhoid Fever as a Menace. W. F. KING. Monthly Bulletin, Indiana State Board of Health, **29**: 10, 147, October, 1926. Too many Indiana public water supplies are notoriously bad, with every inducement offered for typhoid. Analyses made by State Health Department in 1925 show that of 1,378 samples from public supplies, 151 were bad. Most of these bad samples were from supplies obtained from streams, ponds and lakes.—*G. C. Houser.*

Actions Speak Louder than Words. E. L. FILBY, Florida Health Notes, **18**: 11, 159, November, 1926. Outlines work performed by sanitary officers of State Board of Health during emergency brought about in Florida by storm of September 18. At Fort Lauderdale, application of chlorine to the water supply direct from a cylinder was resorted to. Chlorine sterilization was employed at Miami and Hollywood, excessive doses being applied in order to clean up the distribution systems.—*G. C. Houser.*

What You Should Know About Your State Department of Health. Connecticut Health Bulletin, **40**: 12, 279, December, 1926. Work of Bureau of Sanitary Engineering consists of sanitary supervision of public water supplies, public sewage treatment plants, shellfish areas and production methods, and ice supplies; inspection of swimming pools, slaughter houses, summer camps and boarding houses, and roadside water supplies; investigations of questions of private water supply, sewage disposal, and nuisances in coöperation with local health officers.—*G. C. Houser.*

Rural Sanitation. H. E. MILLER. Health Bulletin (North Carolina State Board of Health), **42**: 1, 16, January, 1927. As a result of the enforcement of "The State Sanitary Privy Law," passed in 1919, 126 new public water supply systems and 130 new sewerage systems have been installed. The building of new water works was made possible by the fact that additional revenue from increased consumption brought the system to a self-sustaining basis. The typhoid fever death rate has been materially reduced from the rate of 1918.—*G. C. Houser.*

Cross Connections in Connecticut. W. J. SCOTT. Connecticut Health Bulletin, **41**: 1, 3, January, 1927. Regulations adopted by the Public Health Council provide that after December 31, 1926, no cross connections shall exist between potable and non-potable water supplies, except that installations protected by double check valves of approved type, with adequate facilities for testing, which were in existence on December 31, may be temporarily permitted with the approval of the State Department of Health.—*G. C. Houser.*

Typhoid Epidemic at Watseka. T. J. BROPHY. Illinois Health News, **13**: 1, 21, January, 1927. In October, 1926, Watseka, with a population of about 3,000, had a typhoid epidemic, during which 31 cases and 3 deaths were reported. The outbreak came soon after a flood in the Iroquois River, which receives the sewage of Watseka. It is suspected that the city water supply, which is derived from wells, became polluted during the high stage of the river.—*G. C. Houser.*

Webb-Lattin Water Bill Would Fix Responsibility. Health News (N. Y. State Department of Health), **4**: 6, 21, February 7, 1927. Bill before New York legislature would fix responsibility for failure to take necessary steps when a water supply is known to be dangerously polluted. Bill provides that failure to carry out emergency recommendations of commissioner of health shall constitute presumptive evidence of negligence.—*G. C. Houser.*

Conservation of the Waters of the State by the State Department of Health. H. P. Croft, Public Health News (N. J. Department of Health), **12**: 3–4, 74, February-March, 1927. Policy of the department is that the discharge of sewage into waters of the state shall be so regulated that the inhabitants are not caused injury in health, comfort, or property. In those municipalities that must discharge sewage into waters used as sources of water supply, the department requires that the sewage be subjected to sedimentation, oxidation, and disinfection.—*G. C. Houser.*

Resolution Prohibiting Bathing in Potable Waters of New Jersey. Public Health News (N. J. Department of Health), **12**: 3–4, 100, February–March, 1927. In December, 1926, the Department of Health resolved that no person shall bathe in any stream, lake, or reservoir, the waters of which are the source of a public water supply for domestic use, if, upon examination and investigation, the department determines that bathing pollutes said water for potable purposes.—*G. C. Houser.*

Report of Bureau of Sanitary Engineering, Maryland State Department of Health, 1926. Abel Wolman. 19 pp. Activities of Bureau during 1926 with regard to water supply, sewage disposal, oyster investigations, stream pollution, aerial pollution, and camp sanitation are reviewed. Total value of work represented in plans submitted during year was $3,143,000. The percentage of population using public water supplies has increased from 62 in 1916 to 71.6 in 1926. The percentage using treated supplies increased during this period from 54.9 to 66.3, the percentage using public supplies served with treated waters having increased from 88.4 to 92.7. Studies on stream pollution included conditions in regard to disposal of wastes from pulp and paper mills, garbage reduction plant, canneries, laundries, creameries, pigment manufacturing plant, and steel rolling mills. During period of high fish mortality, investigation showed many of dead and dying fish to be infected with flagellate-like spores. Tables given showing typhoid death rate in Maryland, inclusive and exclusive of Baltimore, and in Baltimore for years 1910–1926 inclusive, the rates being 7.4, 9.7, and 5.2 respectively for 1926. Tabulation of distribution of typhoid deaths in relation to population groups for years 1920–1926 inclusive, shows that major portion of mortality is occurring in populations aggregating less than 2500. Efforts are being made to provide municipal water supplies in populations of less than 1000 now that this has been accomplished to large degree in populations exceeding 1000, and it is hoped that this will improve the typhoid situation. Regulations passed on July 1, 1926, state that "no physical connection shall be permitted between a potable water supply and an industrial, fire, or other auxiliary or emergency

water supply." It was required that all existing cross-connections be removed by October 1, 1926.—*R. E. Thompson.*

Report, Corporation of Madras Water Analysis Laboratory, 1925. S. V. Ganapati. 46 pp. Brief report of work carried out, replete with tables and graphs of results of analyses and studies undertaken. It has been observed that the organic content of the raw water varies inversely with level of water in lake, being excessive during months of April to September due probably to decay of vegetation when lake level is low. The purifying effect of sedimentation and exposure to sunlight is evident in May, June and July, during which period the number of lactose fermenters is less. As in previous years, none of the slow sand filters yielded consistently good results. Hydrogen sulfide was evident throughout the year. Tap samples examined resembled raw water bacteriologically except during an experimental period of one month during which the supply was chlorinated. The dominant organism in the white filamentous growths in filter chambers, etc., previously reported on (cf. this Journal **17**: 271), was found to be Crenothrix polyspora: Vorticella and another organism of "colonial habit," probably Carchesium or Zoethamnium were also found.—*R. E. Thompson.*

Irregularities in the Test for B. Coli in Water. Rudolph E. Thompson. Jour. of Bact., **13**: 209–21, March, 1927. Observations and results of experiments on the problem of non-confirming presumptive positive B. coli tests at Toronto, Canada, are given. The failures are of two types, (1) those probably due to presence of aërobic or anaërobic spore-forming lactose-fermenting bacteria or gas-producing symbiotic complexes, and (2) those in which colon group bacteria were originally present and lost in the confirmatory procedure. The latter only are discussed. Typical examples of results obtained when pollution was known to exist are quoted in which the indicated concentration of B. coli would have been 100- to 100,000-fold greater if the losses had not occurred. These failures are believed to be due to the production of an inhibiting H-ion concentration during preliminary enrichment. It is pointed out that while it is generally known that B. coli is inhibited by the acidity formed by its own growth in carbohydrate-containing media, this fact does not seem to have been seriously considered as a factor in the failure of presumptive tests to confirm. Assuming that the failures were due to the production of a lethal pH, three series of comparative tests were made with standard broth and broth containing dipotassium phosphate. Of 300 tubes each of standard broth and standard broth containing the buffer salt, inoculated in parallel, the total numbers positive confirmed were 166 and 232 respectively. In the majority of instances a much larger number of colonies was obtained from the buffered medium than from the standard broth inoculated from the same sample of water. When the same medium is employed for examination of both 10 cc. and 1 cc. quantities of water, as recommended in Standard Methods of Water Analysis, the composition after dilution with the sample varies widely. To eliminate this variation, three strengths of lactose broth are used in Toronto, the composition and amount per tube being so proportioned that when the desired amount of water has been added the composition of the resulting mixture will be the

same in each case. Three quantities of water are employed, namely, 1, 10, and 100 cc., the amounts of media being 9, 15, and 50 cc. respectively and the strength ratio 1:1.5:2.7, taking the strength of standard lactose broth as unity. The final composition in each case is practically the same as when 10 cc. of standard broth is employed with 1 cc. quantities of water according to Standard Methods. In all the above tests 10 cc. quantities of raw Lake Ontario water and the second strength broth were employed. The modified broth contained 2 grams of dipotassium phosphate per liter, corresponding to 1.33 grams per liter of standard strength broth.—*Frank Hannan.*

Water Supply for Army Railways in France. Paul M. LaBach. Proc. Am. Soc. Civ. Eng., 53: 4, 540–62, April, 1927. The factors ordinarily taken into consideration in the supply and distribution of boiler water for commercial railway purposes are outlined briefly. This is followed by a discussion of the difficulties encountered in changing the water supply and distribution systems of several light traffic commercial railways into suitable installations for a unified military railway with very dense traffic. An outline of the organization of forces used in the work is given, together with a discussion of recommendations for an organization which would aid in simplifying and expediting similar operations. Water for boiler use is one of the fundamental requirements for railroad operation. The tonnage to be hauled was estimated to be 60 pounds per soldier per day at the base ports. About one-third of this would be unloaded before the advance section was reached. The actual tonnage was only 3 per cent less than the estimate. Two million men were in France in November 1918. Estimates of materials and locations of water stations which would be needed in an advance to the Rhine were made. Efforts also were made to procure all materials well in advance of the necessity for its use. It was one year after the United States entered the war before a department that was to be responsible for all water supplies used in the Transportation Service was organized. The tanks of the American locomotives held 4,900 to 5,300 gal. of water. The rate of consumption was 70 to 120 gal. per mile with a locomotive having its full tonnage rating. A maximum span of 30 miles with an average of 20 to 25 miles between water stations was adopted. The standard distributing equipment consisted of a 50,000-gallon wooden tank with 10-inch threaded pipe couplings from the tank to the crane. The rapid increase in the size of the Army produced such a density of traffic as to bring out forcibly the need of adequate watering stations. Lack of suitable material was the most serious factor in delaying construction.—*John R. Baylis.*

Probability of Flood Flows. F. G. Switzer. Proc. Am. Soc. Civ. Eng., 53: 4, 563–69, April, 1927. Frequency curves may be applied to flood data in determining flood flow probabilities. A few curves are given to show how the probability curves are used.—*John R. Baylis.*

The Sanitary Water Board of Pennsylvania. W. L. Stevenson. Water Works, 66: 117–19, 1927. The policies and accomplishments in three years of operation of the Board are outlined.—*C. C. Ruchhoft.* (*Courtesy Chem. Abst.*)

Taste and Odor Removal in Water at St. Paul, Minn. ROSS A. THUMA. Water Works, 66: 124, 1927. The St. Paul water supply is diverted from the Mississippi through a series of lakes and filtered. Copper sulphate treatment to control algal growths in the lakes has been practiced for ten years. Many complaints are received, because of the odors from the algal growths and decomposition of organic matter. Coagulation reduces but does not eliminate the odors. Softening with lime and ferrous sulphate failed to remove the odor. Aëration with 6000 cubic feet of air per million gallons has been found sufficient to reduce the odor to a minimum.—*C. C. Ruchhoft.* (*Courtesy Chem. Abst.*)

Safeguarding the Water Supply of New York City. WILLIAM W. BRUSH. Water Works, 66: 47–49, 1927. The water delivered by the Catskill aqueduct from the Ashokan reservoir, which is 92 miles from New York City, is chlorinated three times with average doses of 0.25, 0.17, and 0.26 p.p.m. before it reaches the city. The water supply obtained from Croton Lake, about 30 miles from the city, is chlorinated twice with average doses of 0.6 and 0.3 p.p.m. before it reaches lower Manhattan. The third system, the Long Island Supply, is a system of infiltration galleries served by three pumping and chlorinating stations and is used largely to supplement the other supplies. These three supplies produced about 213, 67, and 23 billion gallons respectively in 1925.—*C. C. Ruchhoft.* (*Courtesy Chem. Abst.*)

Leakage Surveys in Chicago. ANON. Water Works, 66: 69–70, 1927. Public Works, 58: 56–58, 1927. A review of the leakage surveys made by the water pipe extension division from 1907 to 1924. The surveys showed that universal metering is the only way the problem of the ever increasing water consumption can be solved. At Hegewisch the per capita consumption dropped from 433 to 75 gallons after meters were installed in 1920.—*C. C. Ruchhoft.*

Water Waste Investigation in Syracuse. E. P. STEWART. Public Works, 58: 73–5, 1927. The city, which has 270 miles of mains, is divided into 3 sections, and each section is divided into districts of various sizes for water waste survey. Gauging points were established at strategic locations. The night rate is determined with a Pitot recorder, after isolating the district. If the consumption is low, work on another district is started, but if high, the district is further subdivided and the distribution of the night rate determined. At Syracuse, if the rates are 20,000 g.p.d., or over, per average city block, they are investigated. Leaks are detected with aquaphones and electric leak locators employing a microphone, which are the most valuable aids for the work. Leaks as great as 125,000 g.p.d. have been found, though most leaks vary from 20,000 to 60,000 g.p.d. Syracuse is nearly 100 per cent metered and has a gravity system, but the money used in water waste survey work is considered well spent.—*C. C. Ruchhoft.*

"Water Dogs" in a City Water Supply. R. A. POLGLAZE. Public Works, 58: 97–8, 1927. An Alabama city of 40,000 has had trouble with "water dogs," *amblystoma punctatum*, in the water supply. It was found that they were breeding in an uncovered reservoir. The reservoir was cleaned and the water

treated with copper sulphate. A heavy one-eighth inch mesh was placed over the outlet pipes and a 56-inch fence with the bottom 30 inches covered with one-quarter inch mesh wire cloth was built around the reservoir. Since this work was completed there have been no further complaints due to "water dogs."—*C. C. Ruchhoft.*

The New Water Supply of Wellsville, Ohio. R. D. McGill. Water Works, **66**: 89–96, 1927. Wellsville, which is located on the Ohio River about 40 miles below Pittsburg, has taken its water supply from the Ohio River for many years. Because of the very high pollution of the Ohio at Wellsville this supply was condemned in 1921 and abandoned in 1925. The new supply is taken from an impounding reservoir of 142 m.g. capacity which was constructed by building a dam at the junction of Bailey's Run with Little Yellow Creek. This provides a gravity supply of 2 m.g. per day and will maintain a pressure of 70 pounds in the city mains. The design, construction, and operating features of the system are described.—*C. C. Ruchhoft.*

Alkalimetric Determination of the Hardness of Industrial Waters. C. Belcot. Chem. Ind., **46**: 3, January 21, 1927. Bull. Soc. chim., 1926 (iv), **39**: 1648–1652. The values obtained for the permanent hardness of a water not containing alkali carbonates or hydrogen carbonates by the method of Treadwell or of Pfeifer (Z. angew. Chem., 1902, **15**: 9, 198) often disagree with those obtained by difference. The discrepancy is due to the partial solubility of magnesium carbonate. Hence, in a water containing alkaline-earth and alkali hydrogen carbonates, magnesium sulphate and chloride, and sodium carbonate the total carbonate and hydrogen carbonate is determined by titration. The total hardness is then determined, and the permanent hardness determined after boiling the water and neutralising the alkali hydrogen carbonates with hydrochloric acid. (S. K. T.)—*A. M. Buswell.*

Pollution of Streams in Illinois. Illinois State Water Survey, Bulletin **24**: 1927. This report, prepared in coöperation with the State Department of Conservation, contains information on pollution in each drainage basin by sewage and industrial wastes. The data are both summarized according to counties and also presented in the form of spot maps according to drainage areas.—*A. M. Buswell.*

The Disposal of the Sewage of the Sanitary District of Chicago. Illinois State Water Survey, Bulletin **23**: 1927. Alvord, Burdick & Howson. This bulletin is a publication of a report by Alvord, Burdick and Howson, consulting engineers of Chicago, by order of the Secretary of War and submitted to the District Engineer, U. S. Engineer Office, Chicago. It discusses in detail the amount and type of purification required for Chicago sewage, assuming various diversions of water from Lake Michigan, to safeguard the city's water-supply and to preserve fish-life in the Illinois River. As a basis for the conclusions reached, quantities of valuable scientific data have been compiled.—*A. M. Buswell.*

Summary Report on the Water Resources of California, and a Coördinated Plan for their Development. PAUL BAILEY. California Dept. Public Works Bulletin 12, 1927. This report, with its appendices, completes an investigation of the water resources of California started in 1921. It comprises a survey of water supplies and flood flows throughout the state, a determination of their characteristics, an estimate of the present and future needs for water, and the formulation of a comprehensive and coördinated plan for future development that will insure adequate water supplies for all purposes. A coördinated plan for the development of the waters in major geographic divisions of the state provides for the storage of flood waters for conservation purposes, the transportation of surplus waters of the Sacramento drainage basin to the deficient areas in the San Joaquin Valley, an adequate summer flow in the Sacramento River for navigation and salt water control, the resumption of hydraulic mining in the Sierra Nevada Mountains, the control of floods by reservoirs, the expansion of irrigation along the lower Colorado River in south-eastern California, and the diversion of water from that river to the Pacific slope for municipal purposes.—*A. W. Blohm.*

City Water Supplies of Arkansas. HARRISON HALE. University of Arkansas Bulletin, **20**: 18, November, 1926. Because of the importance of public water supplies, the Engineering Experiment Station, University of Arkansas, began in 1924, a state-wide survey of the public water supplies of that state. The bacteriological and mineral analyses of the waters, together with a brief description of supplies of 82 cities and towns in Arkansas are given.—*A. W. Blohm.*

Proceedings of Fourth Annual Short School, Texas Association of Sanitarians. October 27–30, 1926. These proceedings are divided into seven sections as follows: (1) Aims and objectives of the Association; (2) Organization; (3) Public Health Education; (4) Waste Disposal and General Sanitation; (5) Food Protection; (6) Water Supplies; (7) Disease Control Procedure. **Water Supplies: Sources of Public Water Supplies.** V. M. Ehlers. P. 127. In appraising a spring supply, the source of origin cannot always be traced. If it is fed by surface drainage its flow will be more or less intermittent, and the spring flow should therefore be measured over a long period of time, including wet and dry seasons. In considering well supplies it is desirable to determine the nature and extent of the water bearing strata. A safe and acceptable water for drinking and domestic purposes should be palatable, clear and odorless and should not contain any harmful bacteria, excess of mineral salts or poisonous compounds.—**Standard Practice for Sanitary Protection of Sources and Units in a Water System.** E. W. STEEL. P. 129. Care of watersheds and reservoirs is necessary to produce a water requiring a minimum of treatment. Necessary precautions in the sinking of a well and the construction of basins and small reservoirs and distribution systems are briefly outlined. Valves on cross-connections may leak or be tampered with, especially when it is considered that the personnel of factories and water works changes and that newcomers probably will not understand

the possible consequences of the entrance of polluted water into a public supply. For this reason cross connections should be eliminated.—**Water Purification.** LEWIS O. BERNHAGEN. P. 134. The importance of water as a food makes it essential that it be pure and wholesome. An account of a typhoid epidemic in Minneapolis, an extract from Ellms' "Water Purification" and the United States Public Health Service drinking water standard are given.—*A. W. Blohm.*

JOURNAL

OF THE

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Discussion of all papers is invited

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MANUFACTURE OF FERRIC ALUMINUM BY THE ARGENTINE SANITARY WORKS AND WATER SUPPLY

By Mario L. Negri[1] and Atilio A. Bado[2]

The majority of waters of both North and South America, used as water supply, is muddy and ordinarily can not be directly clarified by simple filtration through sand filters, because the matter in suspension is in the colloidal state and because the water contains dissolved humic substances which are not totally separated by the oxidation of the sand filters.

Due to these causes, the method used in North and South America, especially in the Argentine, for the purification of such waters is a combined method of chemical precipitation by means of aluminum sulphate, decantation of this precipitate and filtration of the liquid thus obtained through sand filters which have a chemical and physical action of clarification and destruction of the organic matter not precipitated by the coagulant.

The muddiness of these waters is due to the suspension or pseudo-solution of the more or less ferruginous clays which form the bed of American rivers. Consequently the aluminum sulphate, acting on the carbonates of the water and combined with the dissolved organic matter, carries into the coagulated form the clay in suspension in the colloidal state.

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[2] Chief Chemist, Obras Sanitarias de la Nacion, Buenos Aires, Argentine Republic.

In summary, the coagulant obtained is a true "laca" formed by an aluminum hydrate combined with the organic matter and mixed with clay. Theoretically and practically the aluminum sulphate in an alkaline water decomposes and precipitate the totality of the aluminum hydrate. The coagulant obtained in the settled deposit, therefore, could be used to regenerate the coagulant employed. During the year 1912 preliminary trials were made which permit us to arrive at the following conclusions:

a. The coagulant used in the clarification of river water can be regenerated from the mud which precipitates in the deposit of decantation in Recoleta's Plant.

b. This same product could be used as a base for obtaining a great quantity of sulphate, taking advantage of the same oxide in the precipitated clay.

RECOVERY OF SETTLED COAGULANT

With the object of carefully studying this problem, a series of tests were made in the laboratory by making the analyses of the mud collected in the deposit of decantation. The mud was afterwards subjected to attack with sulphuric acid.

The mud extracted contains a total of solid matter which varies from 23 to 30 per cent. This is easily deposited and a black or dark brown product of gelatinous appearance is obtained. This is concentrated little by little under the action of air and sun rays and finally after a variable time, from ten to fifteen days, under atmospheric conditions, a solid product is obtained of appreciable resistance that can be broken easily with a hammer. This product pulverized and dried out during five hours at 110°C. has approximately 15 per cent of organic matters. The rest consists of clay and aluminum hydrate easily soluble.

After a series of laboratory experiments we found that the hot sulphuric treatment of the mud previously dried and calcined at a convenient temperature and the concentration of the liquid to a state of crystallization had given a product of small yellow-white pieces of astringent taste. This product has the property of coagulating the clay of the muddy water.

This procedure was patented by the authors under patent number 12626 (Argentine Republic) and was voluntarily and gratuitously granted to the Directory of the Obras Sanitarias de la Nacion in case they decided upon the manufacture of such a product in this country.

Later investigation by Dr. Bado made it possible to substitute for the use of the mud of the settling basin the Pampeano loess, which is found in large quantities under the vegetal cover in the federal state, Province of Buenos Aires, and in other points. This new method permits simplification of the factory installation and the manufacturing process, eliminating at the same time a series of manipulations otherwise necessary, by using the raw material obtained at comparatively low price.

MANUFACTURE OF ALUMINO FERRIC

The Technical Directory of the O. S. N. reported to the Directory of the same Institution requesting the sum of $443,850 (Argentine Currency, equivalent to $177,540, American Currency) for the installation of the alumino ferric plant (on the basis of the Pampeano loess as the raw material) with the capacity to produce 10,000 tons per year.

During the meeting held by the Directory of the Institution on June 23, 1916, it was resolved to approve the plan and the preliminary works presented by the Technical Directors for the installation of the alumino ferric plant and to request of the Ministerio de Obras Publicas (Secretaryship of Public Works) the necessary authorization for the investment of funds.

The Executive Power of the Nation on July 3, 1916, gave out a decree authorizing the installation of the factory on the Recoleta Plant. The construction work began immediately and on April 23, 1917, the factory began its operation uninterrupted up to this date.

SIMILAR INDUSTRIES ELSEWHERE

At the time of finishing the authors' study we were informed of the appearance of an article in Engineering Record, May 8, 1915, under the title of "Columbus Water Works is making its own alum-A revolutionary step in water purification practice," by Charles P. Hoover.

From its contents it appears that the project of reference is similar in all its general principles to the one we have worked out. Our idea of manufacturing the coagulant in this country dates back to the year 1912, in other words 3 years before it was applied in Columbus.

In Columbus they used bauxite, substituting after a while "halloysite."

In Kinston-on-Thames the municipality manufactures the alu-

minum sulphate, employing the bauxite for the purification of its water. This manufacture dates from 1910.

The manufacturing process developed by us differs from the Columbus one in the raw material. We were obliged to have recourse to the pampeano loess, after fruitless attempts to find the bauxite in this country. The adoption of loess is analogous to the Columbus idea to substitute the halloysite for the bauxite.

RAW MATERIAL USED

The raw materials used for obtaining ferric aluminum are: the pampeano loess and the commercial sulphuric acid.

The formation of the pampeano loess is still subject to numerous discussions and nothing is truly known respecting it. Some think

TABLE 1

Composition of the pampeano loess

COMPONENTS	1	2	3	4	5	6
	per cent	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
Silica (SiO_2)	70.58	69.40	70.74	69.62	71.98	69.00
Aluminum oxide	17.70	16.00	16.70	17.80	17.40	16.70
Iron oxide	7.00	7.00	7.00	7.00	6.70	7.20
Calcium oxide	2.26	2.24	2.47	2.42	1.85	3.33
Magnesium oxide	1.83	1.48	1.54	1.51	1.26	1.94
SO_3	0.48	0.99	0.65	0.79		0.44
Alkalies	0.15	2.89	0.90	0.86	0.81	1.39
Loss due to calcination	2.71	3.83	3.21	2.30	2.90	3.28
Water	17.85	14.24	16.89	14.65	16.20	18.00

that the loess is the result of accumulation of dust carried by the wind; others that it is alluvial soil. It is formed by a mass of red-yellow color more or less intense according to its state of humidity, and it is easely broken by finger pressure. It can be kneaded with water and gives a plastic chocolate-colored mass. Chemically it is a double silicate of iron and aluminum.

It is found in abundance in our country on the pampeano formation. From analysis of several specimens near San Isidro Town (Province of Buenos Aires) it shows the results in table 1.

From the inspection of table 1 it may be seen that the loess utilized is of constant composition. The aluminum oxide is 17 per cent and the iron oxide is 5 per cent, with negligible quantities of calcium and

magnesium oxides. The calcium oxide is found in the mineral in the calcareous state. It is hard and cannot be pulverized by the disintegrator, which means that in the acid treatment it is covered with a layer of calcium sulphate which prevents complete attack of the mass.

The water content of the product is variable according to the hygroscopic state of the atmosphere, but in general it may be said that, in a normal surrounding atmosphere of humidity, the water absorption is 15 per cent. This product is spontaneously dried out and its humidity at the time of being employed is not greater than 10 per cent, facilitating thus the disintegration of the material under consideration.

The sulphuric acid utilized is the commercial acid from lead chambers. At present it is furnished by the sulphuric acid factory and is transported by automobile truck to the aluminum factory.

The sulphuric acid has the grade of 55 to 56.5 equivalent to 70 per cent of pure acid. The determination of the grade in Beaumé scale is made in every shipment of the acid and periodically the complete analysis is made in our own laboratory.

At present the sulphuric acid is obtained at the price of $33.48 and $31.10 during the years 1924 and 1925, respectively.

DESCRIPTION OF THE CHEMICAL PROCESS OF MANUFACTURING

The ferric aluminum manufactured is made by treating the pampeano loess with the chamber sulphuric acid at a convenient temperature.

The sulphuric acid is warmed up by means of steam produced in a boiler under from three to four atmospheres of pressure. When the temperature of the acid is higher than 100°C. it is stirred by compressed air during the time of loading the mineral. This operation is done by hand. When the mass is perfectly homogeneous the injection of compressed air is eliminated and the heating continued until 110°C. is reached. At this moment the steam injection is stopped because heat is maintained by itself for a space of more than twenty hours. When the mass is clearly attacked and the cake presents the normal appearance the extraction of the ferric aluminum begins by means of separate washings with cold water strongly stirred with compressed air. The washing is finished when the liquid shows the corresponding density. Before proceeding to the extrac-

tion of the liquid from every washing it is allowed to settle and, by means of a piping system, the liquid is carried to the decanters where it remains quiescent for twenty-four hours.

The operation is carried on by putting in each hopper 6000 kgm. of mineral, 2500 kgm. of sulphuric acid from the lead chambers, and a sufficient quantity of water to obtain a fluid mass. The acid action lasts about twenty hours. After this period the dissolution of the ferric aluminum occurs having been formed by four washings stirred by compressed air; the two first washings are done inside the hopper and the last ones in the washing reservoirs described below. In this way all the product is extracted and finally a yellow-brown liquid is obtained containing about 15 per cent of aluminum and iron sulphates. Under these conditions we obtain the results for every washing shown in table 2.

TABLE 2

Aluminum ferric obtained at different washings

WASHINGS	HOPPER NO. 1	HOPPER NO. 2	HOPPER NO. 3	HOPPER NO. 4	HOPPER NO. 5
	kgm.	*kgm.*	*kgm.*	*kgm.*	*kgm.*
1	2,988	3,047	3,139	2,648	3,067
2	702	647	742	816	869
3	425	449	524	485	455
4	144	85	138	98	132
Total ferric aluminum...	4,259	4,228	4,543	4,047	4,523

The liquid obtained from all these operations is sent to the decanters where, by settling, it deposits the fine clay in suspension in it. The clarified liquids provide a concentrated coagulant solution that may be directly injected into the water supply for its clarification.

For this purpose the liquids from the decanters are sent to big tanks where they are stored and utilized as needed, being injected in calculated doses.

A part of the liquids, instead of being sent to the tanks, is sent through lead pipes to the concentrator tank. In this one, a water stream circulates in the lead pipes placed near the bottom. The continual evaporation concentrates the liquid from 16° to 18° Beaumé to 60 to 66°B.

The idea is advisable of not concentrating the coagulant for the

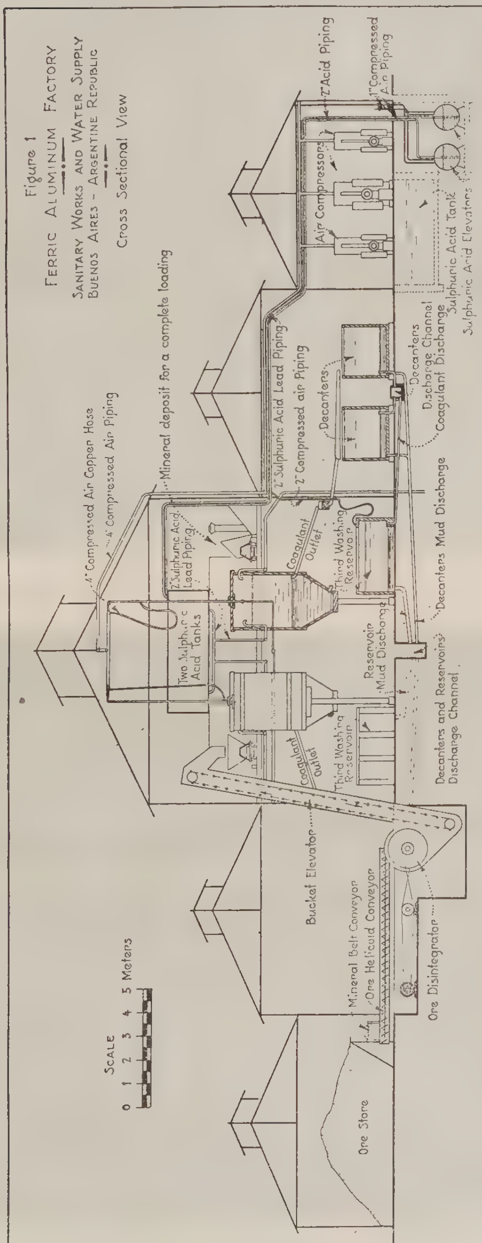
Figure 1
Ferric Aluminum Factory
Sanitary Works and Water Supply
Buenos Aires - Argentine Republic
Cross Sectional View
Scale
0 1 2 3 4 5 Meters
4" Compressed Air Copper Hose
4" Compressed Air Piping
Mineral deposit for a complete loading
2" Sulphuric Acid Lead Piping
2" Compressed air Piping
2" Acid Piping
1" Compressed Air Piping
Air Compressors
Decanters
Decanters
Discharge Channel
Coagulant Discharge
Sulphuric Acid Tank
Sulphuric Acid Elevators
2" Sulphuric Acid Lead Piping
Two Sulphuric Acid Tanks
Coagulant Outlet
Third Washing Reservoir
Reservoir Mud Discharge
Decanters Mud Discharge
Coagulant Outlet
Third Washing Reservoir
Decanters and Reservoirs Discharge Channel
Bucket Elevator
Mineral Belt Conveyor
One Helicoid Conveyor
Ore Disintegrator
Ore Store

FIG. 1

FIG. 2

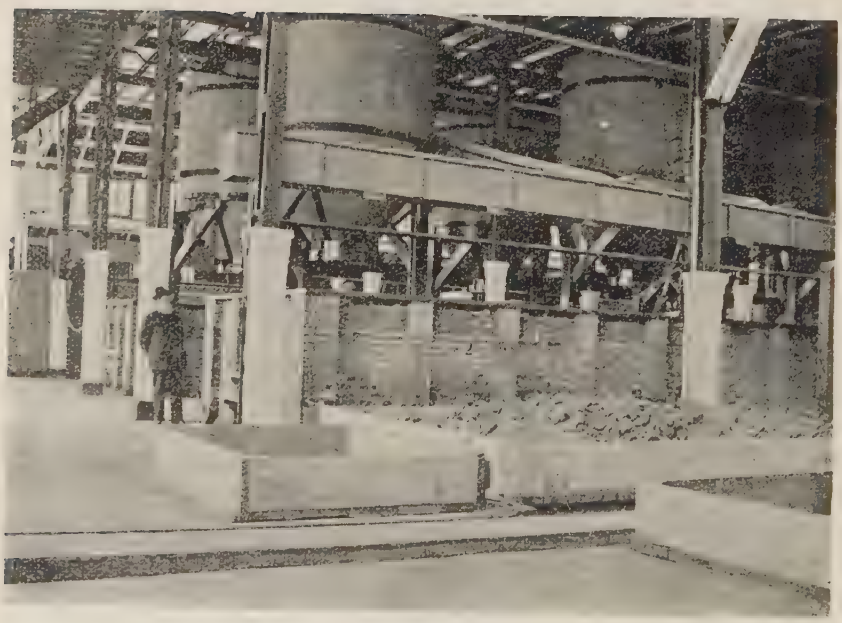

FIG. 3

FIG. 4

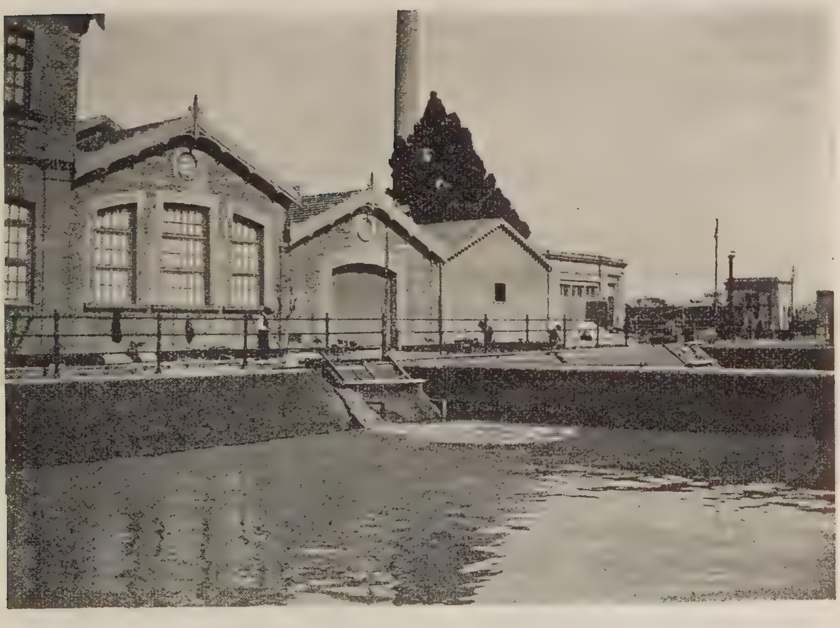

FIG. 5

Federal State, which constitutes more or less 93 per cent of the actual consumption, for the great economy of coal and hand work in the elimination of those two operations. At the same time it decreases enormously the expenses in transportation, breakage in dissolution of the solid coagulant.

The liquid once concentrated, we obtain a syrup of 60° to 66°B. of a green-yellow color which, on cooling, solidifies into a compact light green mass; breaking it by hammer it can be pulverized in a special triturator, obtaining thus a white fine powder, very lightly blue, of astringent taste, soluble in water giving a yellow solution that has the coagulant properties; that is, when poured into the River Plate water it can provoke coagulation.

The composition of the solid matter we have just described is shown in table 3.

TABLE 3

Composition of the solid ferric aluminum

	1	2	3	4	5	6
	per cent	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
Insoluble in water	0.72	1.31	1.20	1.70	0.55	1.08
Aluminum oxide	12.34	12.24	11.06	11.28	10.66	11.10
Iron oxide	4.62	5.80	6.44	5.78	6.04	5.76
Calcium oxide	0.29	0.28	0.30	0.25	0.30	0.31
Magnesium oxide	1.46	1.54	1.11	1.41	1.30	1.51
SO_3	39.63	40.90	39.42	39.01	40.92	39.62
Alkalies	1.72	0.92	1.62	0.56	0.73	0.92
Water	39.22	37.01	38.85	40.01	39.50	39.00

GENERAL DESCRIPTION OF PLANT

The factory under consideration occupies 23,000 square feet, located in the Recoleta Plant in front of the new decanters and between the pumping machinery building and the filters. Figures 1 to 5 show the general arrangement of the plant.

PRODUCTION COST

Table 4 shows monthly curves of sulphuric acid cost and of the ore employed in the manufacture of ferric aluminum. It also shows the cost of manufacturing.

Figure 6 shows the decreasing cost of the ferric aluminum beginning with the year 1924, due to our own manufacturing of the sulphuric acid the price of which has proportionally decreased.

Table 4 shows the yearly details of the manufactured products, the total cost of manufacturing and the unit cost of ferric aluminum. The total amount produced up to the end of 1926 is 123,334.62 tons at a total cost of $7,224,401.47 (Argentine currency), the average cost being $53.98 per ton, or $21.59 (American) per ton.

COAGULANT EFFICIENCY

The efficiency of the manufactured ferric-aluminum as a coagulant is practically perfectly demonstrated by the amount used in the plants belonging to the O. S. de la N.

A comparison of the average doses of coagulant shown in the yearly report of the Institution shows that they have not varied markedly. It must be noted that down to the middle of year 1917 the coagulant consumed was from foreign countries.

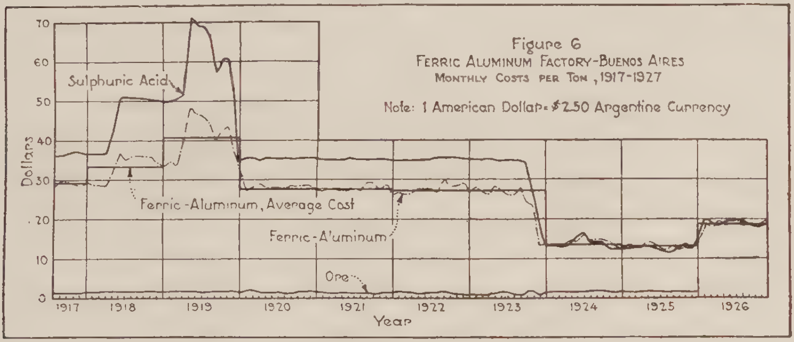

FIG. 6

ECONOMIC RESULTS

The cost of manufacturing the coagulant up to December 31, 1926, reaches the amount of $7,224,401.47 (Argentine currency). We must note the great economy to the State on account of the installation of this process.

The price of the foreign aluminum sulphate taken from the public purchases and the quotations since 1917 until 1925 varies between $420 to $70.50, as shown in table 5.

Calculating then the cost of the coagulant in case it had not been manufactured in this Country, there would have been expended annually the amounts shown in table 6.

TABLE 4

YEAR	TONS	TOTAL COST IN DOLLARS (ARGENTINE CURRENCY)	UNIT COST IN DOLLARS (ARGENTINE CURRENCY)
1917	3,274.12	236,188.69	72.13
1918	7,342.14	614,021.57	83.63
1919	9,341.20	949,991.96	101.69
1920	8,983.10	616,599.98	68.64
1921	10,491.70	727,103.65	69.50
1922	12,296.26	846,474.54	68.84
1923	15,309.28	1,058,943.10	69.17
1924	15,681.20	539,249.44	34.39
1925	19,053.00	635,767.47	33.37
1926	21,562.41	1,000,061.07	46.38

TABLE 5

Price of foreign aluminum sulphate

YEAR	DOLLAR (ARGENTINE CURRENCY)
1917	281 to 450
1918	Without quotation
1919	420.00
1920	156.83
1921	175.27
1922	99.90
1923	91.00
1924	91.00
1925	70.50
1926	72.60

TABLE 6

Probable costs of purchased aluminum (Argentine currency)

	TONS	DOLLARS PER TON	TOTAL (DOLLARS)
1917	3,274.120	281.00	920,027.72
1918	7,342.141	281.00	2,063,141.62
1919	9,341.203	420.00	3,923,306.26
1920	8,983.100	156.83	1,408,819.57
1921	10,490.700	175.27	1,838,704.99
1922	12,296.260	99.90	1,393,144.75
1923	15,309.283	91.00	1,426,989.20
1924	15,681.200	91.00	1,343,236.50
1925	19,053.000	70.50	1,343,236.50
1926	21,562.413	72.60	1,565,431.17

As we have already stated, instead of spending $17,226,038.22 in the purchase of 123,333 tons of coagulant, we spent $7,224,401.47 due to our own manufacturing, representing thus a total saving of $10,001,636.75 equivalent to $1,000,163.67 for each one of the 10 years of manufacturing or approximately $400,000, U. S. currency.

The great advantages obtained by the Nation through this industry may plainly be seen and they will be still greater on account of the future enlargement to be made in the acid factory, in order to obtain a capacity of 60 tons every 24 hours.

THE IMPOUNDING WORKS OF THE SAN DIEGO WATER SYSTEM[1]

By R. C. Wueste[2]

Even the most causal consideration of the climate, topography and geology of San Diego County discloses that the sources of available water supply for the City of San Diego within a fifty mile radius are very limited. In this sector, there are no perennial streams or natural lakes. Ground water in any quantity is pretty generally confined to the narrow ribbons of water-bearing drift forming the valley floors of the main drainage channels which score the county from the crest of the Coast Range on the east to the ocean shoreline on the west.

Although San Diego is not limited to seek water within fifty miles of her population center, it is nevertheless a fact that other sources of worth-while proportions are only to be reached by going four times that distance.

Confronted by these conditions and limitations, the one logical process of developing a dependable supply within the county has been adopted. This implies the construction of dams at favorable basin mouths, in which the locality fortunately abounds, for the impoundment, retention and storage of the winter runoff resulting from the impressment of the rainy season storm clouds upon the inclined plane of the county watershed area. The County of San Diego is a noteworthy example of the application of the principle of artificial lake creation to transmute an erratic surface source of supply resulting from the vagaries of scant seasonal rainfall, into dependable and regulated gravity duty. The first applications of this principle of development date back forty years and had their origin in the forced realization of the futility of any other means of producing adequate supplies.

[1] Presented before the California Section meeting, October 28, 1926.

[2] Supervisor, Municipal Impounding System, San Diego, California.

POPULATION GROWTH

Rapid population growth of Pacific Coast communities has furnished many surprises. The case of Los Angeles has been nothing short of phenomenal. In a twenty-year period from the time she was San Diego's present size of 150,000, her population increased to three-quarter million inhabitants, an average population increment of 30,000 per annum. San Diego's present sustained growth is about one-half this rate, with good reason to believe that it will soon approach a rate equal to that of Los Angeles. County or regional population increase is noted to continue parallel with the City's growth, so that it is evident that local water developments must follow one another in rapid succession.

COUNTY WATER RESOURCES

The runoff producing area of San Diego County comprises a 30- to 40-mile wide belt of mountainous territory mainly of granitic composition, defined on the east by the divide overlooking the Imperial Valley and on the west by the line of nearest-the-coast dam and reservoir sites. The area east of this divide is arid and almost rainless except for summer thunder storms. It drains to the east away from San Diego, falling away very abruptly from elevations between 4000 and 6000 feet to elevations below sea-level in Salton Sink. This line of demarcation between the area of highest county rainfall of 40 inches and the area of almost no rainfall is astonishingly distinct. Rainfall west of this line of dam-sites is 10 inches or less.

The county watershed area is about 2000 square miles. Areas lying north of the county boundary line in the Santa Margarita Basin and south of the international boundary line in the Tia Juana Basin which may be considered tributary to San Diego, bring the total to 3585 square miles. The most reliable estimates show that this area when fully developed, will yield a little less than 200 m.g.d., considering surface water only. Ground water sources are regarded as emergency supplies and, if used as such, can be shown to increase materially the safe net yield limit just quoted.

At present San Diego County's water supply is about one-fifth developed from the storage and correlative safe net yield viewpoints. The chief reason why the runoff producing area in the county is not fully developed today is that of cost. Although in other sections of the United States, water development can be and is made in advance

of population,—here, on account of its high cost, such development must wait upon the influx of people and money. However, the rapidly increasing preciousness and demand for water will compel complete development within twenty years.

FINANCIAL LIMITATIONS

To carry these general statements just a little farther, the local quantitative relationship between population and safe net yield of water supply, is that 10,000 people require 1 m.g.d. of safe net yield at 100 gallons per capita per day, including all municipal uses.

Monetarily, San Diego's assessed valuation of property has corresponded very closely to her population curve with a ratio of about $1200 per capita. Only 15 per cent of this is available for bonding for all purposes. When it is realized that the capitalization by means of bond issues of the city's present supply works of reservoirs, dams, transmission, distribution works and appurtenances averages one million dollars per million gallon daily of safe net yield, the intricacies and limitations of the local problem, other than physical, tax the utmost ingenuity of the hydraulic engineer.

HISTORY AND DESCRIPTION OF CITY'S WORKS

San Diego's water supply problem began of course with the first settlements here. During the rainy season the arroyas and ravines held living water. The rainy season over, the creek bottoms furnished ground water for the nuclear community and pioneer agriculturists. The padres who founded the San Diego Mission in the late eighteenth century at the upper end of Mission Valley developed a diversion gravity supply for the needs of the Mission, the boldest attempt for a hundred years to produce a water supply independent of the vagaries of rainfall. With the settlement, in 1867, of "New Town," where San Diego's business section stands today, and the hectic boom of 1886–1887, well supplies within the city limits were quickly seen to be inadequate. The pioneer storage developments on the San Diego and Sweetwater Rivers followed. Conception of similar developments all over the county dates back to this period. The collapse of the boom, the drouth of the late nineties ending in 1904, the community's struggle for existence, the reversion to the Mission Valley sands for a city water supply, the far-sightedness and resources of the late Mr. Spreckels in developing the Cottonwood-Otay supply, the City's gradual awakening from lethargy and its

final irresistible momentum and accelerated growth, justifying and making necessary all the later developments—form colorful and romantic epochs in local water development history.

At the present time we find partial development of the San Luis Rey, San Dieguito, San Diego River, Sweetwater, Cottonwood and Otay drainage areas, presenting dams and accessory structures of a variety of types. The City at the present time owns and controls the dams and reservoirs on the San Dieguito, Cottonwood and Otay drainage basins and accessory structures, serving same, as shown in tables 1 and 2.

With due respect for the admirable work of local pioneer engineers and promotors, some of their efforts indicate errors in judgment, due

TABLE 1

Dams and reservoirs

NAME	TYPE	HEIGHT ABOVE STREAM-BED	YEAR BUILT	COST	RESERVOIR CAPACITY	SAFE NET YIELD
		feet		*dollars*	*m. g.*	*m. g. d.*
Morena	Loose rock fill	166	1912	1,400,000	17,492.8	4.0
Barrett	Concrete gravity arch	179	1922	1,650,000	14,512.2	4.4
Upper Otay	Concrete arch	80	1901	80,000	835.7	0.5
Lower Otay	Concrete gravity arch	149	1919	745,000	18,979.5	3.3
Chollas	Earth fill	46	1906	70,000	90.7	
Hodges	Concrete multiple arch	130	1918	500,000	12,284.3	4.3
San Dieguito	Concrete multiple arch	51	1918	50,000	368.6	

probably mainly to lack of reliable data on runoff. The productivity of watersheds and the resultant safe net yield of developments were in instances greatly overestimated. It is not to be wondered at that certain developments have been put in with little regard to adhering to a logical schedule of sequence. Today, the wealth of engineering reports on the local water supply problem and the cumulative record of performance of watersheds and reservoirs makes possible a fairly accurate analysis of the local situation.

It was not until very recently, however, that a plan of development by the city was formulated by city manager, F. A. Rhodes, detail-

TABLE 2

Accessory structures

NAME	TYPE	DESCRIPTION	YEAR COMPLETED	COST	CAPACITY
				dollars	
Dulzura Conduit Extension	Concrete lined canal	6.29 miles trapezoidal ditch, box syphons, metal flumes, concrete drops	1915	185,000	40.0 m.g.d.
Dulzura Conduit	Concrete lined canal	11.0 miles trapezoidal ditch, wood flume and tunnel, grade 0.08 per cent, bottom unlined	1909	521,000	40.0 m.g.d.
Lower Otay Filtration Plant	Rapid pressure	24 8 x 20 horizontal units	1915	125,000	12.0 m.g.d.
Otay-San Diego Pipe Line	Continuous woodstave and cast iron	19.15 miles compound line, 40-inch, 36-inch, 34-inch, 32-inch, 30-inch, 24-inch	1906	529,000	7.8 m.g.d.
Bonita Pipe Line	Riveted steel	8.08 miles 28-inch No. 0 Riveted steel	1915	220,000	6.8 m.g.d.
Chollas Booster Pump	Electric centrifugal	Double suction 2 stage 250 h.p. motor	1914	15,000	12.0 m.g.d.
Mission Valley Pumping Plant	Electric centrifugal	12 4-inch, 4 stage vertical 10 h.p. and 2 10-inch, 4 stage 250 h.p.	1914	100,000	5.0 m.g.d.

Hodges Conduit	Concrete lined canal	4.65 miles trapezoidal ditch, circular reinforced concrete syphons, metal flumes	1918	200,000	9.7 m.g.d.
Lockwood Mesa Gravity Line	Reinforced concrete pipe	6.72 miles 24-inch, 26-inch, 27-inch reinforced circular concrete pipe	1918	108,209	3.9 m.g.d.
Lockwood Mesa Reservoir	Open concrete lined	Trapezoidal concrete lined basin, 60 x 100 bottom, 84 x 124 top, 8 feet deep	1918	10,000	0.5 m.g.
Del Mar-La Jolla Pipeline	Machine banded wood-stave and reinforced concrete	10.55 miles 16-inch and 18-inch diameter	1920	200,000	3.5 m.g.d.
Torrey Pines Reservoir	Open concrete lined	Square trapezoidal concrete lined basin 200 x 200 bottom, 230 x 230 top, 10 feet deep	1920	25,000	3.0 m.g.
Torrey Pines Filtration Plant	Rapid pressure	7 8 x 20 horizontal units	1926	40,000	3.5 m.g.d.
Torrey Pines Booster Pump	Electric centrifugal	3 6-inch, 2-stage pumps; 3 125 h.p. motors	1926	8,000	4.5 m.g.d.

Note: The above list does not include the distributing system within the city, or its accessory standpipes, service reservoirs, filter plants and booster pumps.

ing step by step the proposed developments for the next twenty years which will keep the safe net yield available to the city ahead of the expectancy curve of population. This strategical denouement of the latent resources embraces progressive and complete development of the San Dieguito, San Diego and Tia Juana drainage areas.

PROBLEM OF SAFE NET YIELD

One of the most interesting and engrossing phases of local hydraulic engineering research is that of safe net yield and its allied subjects. Safe net yield may be defined as the quantity of water which a development will yield for continuous withdrawal, under continued climatic conditions in the future, similar to those of which we have record in the past.

The first of these conditions is rainfall, records of which at San Diego date back seventy-five years. The mean seasonal rainfall at San Diego is less than 10 inches, increasing about one-half inch with each 100 feet of topographical altitude to the eastern rim of our watershed area.

The characteristics of this rainfall are the erratic, gross seasonal variations from the mean and the erratic occurrence of the rainstorms which go to make up the gross seasonal totals. The seasonal variations have run 50 per cent below mean and 250 per cent above mean.

The relationship between rainfall and runoff is far from direct or uniform. During subnormal seasons of rainfall, no runoff whatsoever has been known to reach a given reservoir, all rainfall being dissipated by the operation of such factors as capillary retention and vegetable transpiration. Under certain storm conditions it might happen that all the rainfall descending upon a certain area would reach a given measurement plane as runoff. This residual coefficient may then lie somewhere between 0 and 1, and runoff from certain drainage basins has actually been found to vary from nothing to ten times the seasonal mean which for the county watershed area is about 120 acre feet per square mile. Maximum runoff rates are estimated as high as 400 second feet per square mile.

Once the runoff has been harvested behind one of our dams, the factor of evaporation immediately becomes operative. Evaporation is classified as gross and net, the latter being gross evaporation as offset or diminished by rainfall descending upon the same reservoir surface from which the evaporation has taken place, in the same time period. Since both evaporation and rainfall increase with altitude, the net evaporation is somewhat uniform for all portions of the county.

The controlling influences on safe net yield are, therefore, the size and mean altitude of the tributary watershed, the size or impounding capacity of the control reservoir, ranging in ultimate developments between 4 and 6 billion gallons per million gallon daily, and its efficiency index, that is, the ratio of its volume to its exposed surface area. Reservoirs can and do differ greatly in this latter characteristic, which in turn affects reservoir performance.

The city is in possession of reservoir performance computations on practically every constructed and potential development in San Diego County. These computations necessarily predicate certain factors upon which there is no observation or record from other factors upon which there is observation or record. The computations may with safety be commenced with the 1883–1884 season, the greatest locally within the period of rainfall records, and if safely carried over the critical dry period 1897–1904, will represent safe net yield in accordance with the definition before given. In general, the major developments of the county will show a safe net yield of between 40 and 50 per cent of the mean seasonal runoff.

Often it may be shown that storage adjustment or transfer from one reservoir to another is advisable from a standpoint of monetary economy or water loss prevention. Such adjustment is made annually on the city's Cottonwood Otay System and is contemplated on the Sutherland, San Vicente and El Capitan projects.

COST OF DEVELOPMENT

From all the preceding, it is evident that the cost of water locally must be high. Collection and transmission properties operated and controlled by the city have been acquired under bond issues and equivalent payments, totalling $11,000,000.00. Bonds on the distribution system represent another $3,000,000.00 investment. This capital investment represents over $600,000.00 of interest annually, at the interest rates on the actual bonds, most of which are not yet redeemed. The most recent figures place the cost of water at the tap at 24.1 cents per 1000 gallons. This may be segregated into

	CENTS	PER CENT
Interest	12.05	50
Depreciation	4.82	20
Maintenance and Operation	7.23	30
	24.10	100

The city is 100 per cent metered and the selling price of water is 20 cents per 1000 gallons. The excess of cost over selling price naturally is met in the tax levy on assessed valuations. In the past, this procedure was regarded as advisable, in view of its effect on the non-user holding vacant property.

Locally, the day of cheap water properties or water rights is past. As water becomes more precious the cost and valuation of these fundamentals will increase.

RECREATIONAL USE

Contrary to general practice elsewhere, San Diego allows recreational use by the public of its impounding reservoirs. The practice is in fact universal in the county and has a commercial aspect which is increasing in importance, at least as fast as regional population growth.

The physical factors surrounding the local methods of water development account for our ability to continue this practice with no deleterious effect upon the quality of the water. It appears that sparsely populated watersheds, large reservoirs, long storage (from one to ten years) common sense restrictions and ample sanitary facilities for the hunters and fishermen may perpetuate this unique privilege to our citizenry.

QUALITY OF DEVELOPED SUPPLY

The same factors which encompass and make difficult and expensive the development of water for San Diego, fortunately also are accountable for its high purity and attractive esthetic quality. Watersheds of granite formation and by nature not fitted to dense agricultural population and subject to nine months' natural sterilization by air and sunlight, long storage implying immolation of bacteria are responsible for the high quality of the raw water.

With efficient plankton control, color, odors, and tastes may be kept to a minimum.

Surface temperatures follow a curve during the year similar to the mean air temperature. Draft is usually advisable from the upper strata of our reservoirs. Transmission to the city does not change these temperatures materially. In consequence, we receive water as warm as 80 degrees at our taps in midsummer and as low as 57 degrees in winter.

Even with a raw water suitable for consumption without any

treatment, San Diego employs the purification processes of rapid sand filtration and chlorine disinfection. Three separate filtration plants are in use on three of the arteries entering the city. They are all of the pressure type and represent the greatest number of units employed on municipal water anywhere in the United States. Disinfection follows filtration.

San Diego's position on the honor roll of the seventy-seven American cities with over 100,000 population and her first position in the group of ten Mountain and Pacific state cities of that size in the 1925 typhoid fever survey of the American Medical Association speak with significant eloquence of the purity of its water supply.

CONCLUSION

We feel that nowhere in the United States is the question of water supply development of greater vital importance to a growing community, endowed with many other and diversified blessings, than in San Diego. Local development is but a fourth as old as developments elsewhere in the United States, yet we feel that here man's interference has shapen the development of a supply in greater measure than where water is less precious.

The involved relationship of the limited and sporadic natural gift of rain and the high cost of control and conversion of the resulting runoff to sustained duty is unique and intensely interesting. Forty years ago the first settlers' needs stood impotently by, while wild floods coursed to the sea. Step by step our water history will show these same floods brought to rest and released as silver threads for the community's use, growth and advancement.

RECORDS OF THE PERFORMANCE OF SMALL METERS[1]

By W. E. MacDonald[2]

To meter successfully the water of any city requires the organization of a separate branch of the service whose duty it is to set, test, read, repair and build up a system of cost records. The records compiled should be complete in all details so as to permit a ready analysis of all types of meters, both as to their cost of maintenance and accuracy in service.

The water meter of to-day is a unit used for the measurement of water. It is vitally important that this unit maintain its accuracy during its lifetime, for its failure results either in the water company delivering water for which no money is collected or the private consumer is charged for water which he does not receive. Neither of these conditions are desired by the responsible head of water departments. It is with these thoughts before me that I present a system of costs and accuracy tests for the guidance of a water department, to maintain a high degree of accuracy in the registration of its meter at a minimum of cost.

Preserving records of the cost of any work is valuable of itself because it reveals a cost of the particular undertaking, but that alone is of minor importance compared with the valuable information gained from such records when applied to some new scheme. This is equally true in water meters. The information gained from duration tests, extending over a period of many years of various makes of meters, is a source of valuable information at the time of purchase of new meters.

To purchase water meters intelligently it is essential to have data on the following important factors.

Costs:
- a. Initial
- b. Maintenance

Results of tests for:
- a. Pressure, loss of head, capacity and accuracy in service

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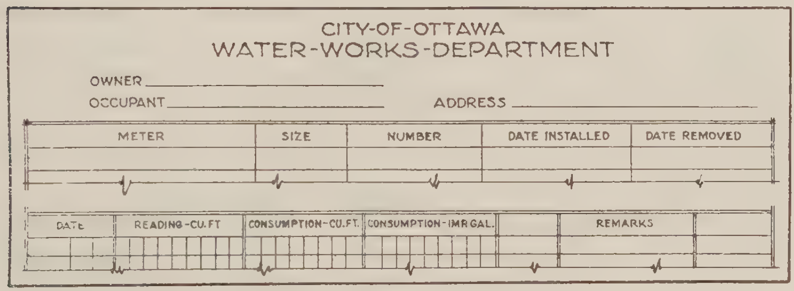
[1] Presented before the Buffalo Convention, June 10, 1926.

[2] Engineer, Water Works, Ottawa, Can.

Unless the buyer has previously purchased meters of all types and has a definite record of each in service, he is not in a position to judge the relative merits of meters as to cost of maintenance and accuracy in service. While it is quite true that any new meter may be tested for accuracy and sensitiveness on small flows and a comparison made of meters tendered on, yet, in the opinion of the writer, such tests are not of much importance, for, when new, all meters can be made accurate and sensitive to a degree, but it is only after a long period of service that the actual merits of the various meters may be determined.

To be in possession of full information covering all types of water meters it is recommended that two complete sets of books be maintained, one showing a record of the consumption to all premises under


CITY-OF-OTTAWA
WATER-WORKS-DEPARTMENT

OWNER

OCCUPANT ADDRESS

METER	SIZE	NUMBER	DATE INSTALLED	DATE REMOVED

DATE	READING-CU.FT	CONSUMPTION-CU.FT.	CONSUMPTION-IMP.GAL.		REMARKS	

FIG. 1. CONSUMERS' RECORD SHEET

meter and the other a true record of the individual performance of every meter. The two forms of ledgers prepared for use in the city of Ottawa and which have worked out very efficiently contain the information shown in figures 1 and 2.

By the adoption of these two sets of ledgers with entries correctly made, it is possible for any member of the staff to prepare comparative charts on the actual performance of all meters in service and to determine successfully what it is costing the municipality for different makes of meters to register accurately each million gallons of water. In recording the consumption of water, both in meter readers copy and on permanent ledger, it is desirable to show each revolution of the meter, so that the figures are carried forward and, without any unnecessary searching of readings, the true history of the meter is at once apparent.

METER TESTS

It is not my intention to go into the details of the procedure to be adopted in the testing of meters, as you are all familiar with this practice, but in passing I should like to state that I consider the standard specification for cold water meters of the American Water Works Association, dealing with minimum flows, should be made very much more stringent than it now is, since it permits too great a variance on mean flows, while the present minimum flow is not sufficiently low to prove the sensitiveness of meters under test.

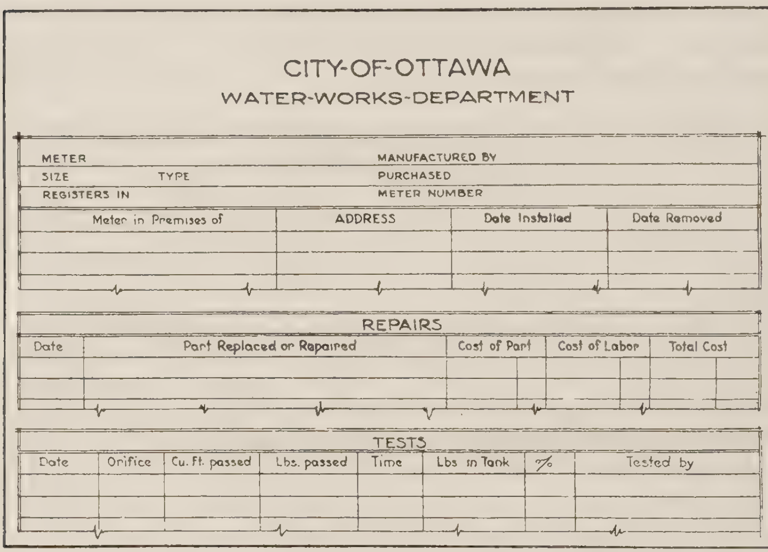


FIG. 2. METER RECORDS SHEET

The following specification pertaining to the registration of small cold water meters has been adopted by the City of Ottawa.

Registration

The registration on the meter dial shall indicate the quantity required to be not less than 98 per cent, nor more than 101 per cent of the water actually passed through the meter; while it is being tested at rates of flow within the limits specified herein, under normal test flow limits. There shall be not less than 95 per cent of the actual flow recorded when a test is made at the rate of flow set forth under the minimum test flow.

SIZE	NORMAL TEST FLOW LIMITS	MINIMUM TEST FLOW	SIZE OF ORIFICE	PRESSURE
inches	*gallons per minute*	*cubic feet per minute*	*inch*	*pounds*
$\frac{5}{8}$	1– 20	0.033	$\frac{1}{32}$	78
$\frac{3}{4}$	2– 34	0.033	$\frac{1}{32}$	78
1	3– 53	0.1	$\frac{1}{16}$	78
$1\frac{1}{2}$	5–100	0.375	$\frac{1}{8}$	78
2	8–160	0.375	$\frac{1}{8}$	78

PERIODICAL INSPECTION

In regard to the periodical inspection of meters, it has been found by actual experiments that no definite term of years nor one complete cycle can be adopted, but rather the period of testing of small meters depends primarily on the make of meter and the quantity of water passed.

From actual observation information has been secured whereby tables for the various sizes of meters have been prepared which set

TABLE 1

MAKE OF METER	QUANTITY OF WATER PASSED
	cubic feet
Type A	60,000
Type B	75,000
Type C	125,000
Type D	150,000
Type E	200,000
Type F	200,000

The letters above refer to different makes of meters.

forth the different makes of meters and the maximum quantity of water which is registered before meters are returned to shop for official test and any necessary repairs. Table 1 was adopted for $\frac{5}{8}$-inch size.

These figures are subject to revision from time to time based on actual results obtained by changed conditions on different makes of meters.

WELL WATER RECESSIONS IN IOWA[1]

By James H. Lees[2]

Well waters of Iowa may be grouped into two classes, so far as their origin is concerned. These are waters derived from the glacial drift, with its interbedded sands and gravels, and those obtained from the underlying bed rock. The great body of the glacial drift consists of more or less pebbly compact clay which absorbs water rather slowly, holds but little and yields it grudgingly. Associated with the mass of this clay, or till, however, are bodies of sand and gravel, some of them more or less lenticular and of limited size, some of them with more uniform dimensions and of very considerable extent, either as widely distributed layers or as long narrow accumulations filling channels in glacial drift or in rock. Such bodies make excellent reservoirs and yield their stores of water readily enough, except in cases where the sand is very fine. Another type of material which is associated with the glacial till, although it is of eolian rather than strictly glacial origin, is the loess—a very fine-textured clay or silt, typically without sand or pebbles, although these are found locally, especially near the base of the loess deposit. Despite its fine grain and texture the loess is very porous and transmits water quite freely, hence it, and especially its sandy base, forms an aquifer of some importance.

FIVE DRIFT SHEETS

Five glacial drift sheets have been recognized in Iowa. The oldest of these, the Nebraskan, covered the entire state and apparently it still constitutes the major fraction of the glacial deposits of western Iowa at least. A basal sand seems to be widely present and supplies a number of wells which penetrate the overlying beds. A second drift sheet, the Kansan, covered all of Iowa except the northeast

[1] Presented before the Chicago Convention, June 9, 1927. By permission of the State Geologist.

[2] Assistant State Geologist, Iowa Geological Survey, Des Moines, Iowa.

corner and forms the surface drift of southern and northwestern Iowa. It is separated from the Nebraskan by a generally distributed gumbotil, a dark gray, very fine-textured gumbo clay which is residual from chemical weathering of the underlying till and which forms a floor for the basal sands which are related to the Kansan drift. A narrow strip of southeastern Iowa between Davenport and Fort Madison is covered by Illinoian drift, which resembles the older drifts in general character, in the presence of embedded and basal sands and in being overlain by gumbotil. Most of the northeast quarter of the state is covered by Iowan drift, which is notable for its exceptional thinness and for the great deposits of loess which mark its boundaries and spread in an ever-thinning blanket over the older drifts. Loess of approximately the same age is piled up also in thicknesses of thirty to a hundred feet or more along the bluffs of the two bordering rivers of the state and in lesser quantities along the Des Moines and over the intervening territory. In north-central Iowa, however, the Des Moines valley loess is mantled by the Wisconsin drift, the youngest of the glacial deposits of the state.

TOPOGRAPHY OF DRIFT AREAS

The topography of the northeast corner of Iowa, the only part of the state uninvaded by glaciers later than the Nebraskan, is exceedingly rugged, the drift is almost entirely eroded away and the only unindurated materials are alluvium and coarser filling in the valleys and residuum from rock wastage and loess on the uplands. The valley filling furnishes an abundant and permanent supply of water to wells sunk therein, but the upland covering is thin and over much of the area is well drained so that comparatively few wells find sufficient water in it, but are compelled to enter the underlying rocks. The thickness of the Kansan and Nebraskan drifts of southern Iowa is much greater than that of the northeast corner and reaches a maximum of 500 feet or more in some of the western counties. The topographic features are markedly erosional, although some upland tabular divides still indicate the level character of the original drift plain. Near the "breaks" water is likely to be found only at considerable depths and this is true of some parts of the uplands, as where no gravel beds have been penetrated and hence wells must be sunk through the entire thickness of the drift to search for the sand bed at its base. The deep, wide valleys of this province supply many

town and farm wells although even here some failures are to be noted and recourse must be had to ponded surface supplies. The characters of the Illinoian drift plain are similar to those of the province just described except that here are three drifts with their contained gravels and sands from which water may be drawn.

The loess overlying the three older drifts in southern and northwestern Iowa has always been utilized as a source of water for shallow wells, which have generally been sunk to the basal sand layer. In some parts of western Iowa a good many wells are supplied from a layer of gravel which lies immediately under the loess, but which seems to be residual from the wastage of the drift rather than depositional, as a part of the loess. The Iowan drift plain of northeast Iowa has typically a rather gently rolling surface, which, where the drift is thin, permits of fairly free natural drainage of the ground water. Where the thickness of the drift is greater, ranging up to 200 to 300 feet, the water content is much larger. The topography of the Wisconsin drift sheet is very immature so that except near the few larger streams the glacial materials are water-logged and the head of water is high, permitting the use of many shallow wells.

INTERMEDIATE WATER SUPPLIES

It is impossible of course to distinguish sharply between the waters of the glacial drift and those of the country rock, as there is naturally a continuous interchange, especially where the rock under the drift is limestone or sandstone. Not only are these rocks sufficiently porous to permit absorption of the overlying water, but wherever the solid strata are overlain by broken or residual materials these latter hold a supply of water and in many cases serve as a valuable aquifer. Where the country rock is shale, however, it acts as a confining rather than a contributing agent.

DISTRIBUTION OF STRATIFIED ROCKS

The stratified rocks come up to the glacial beds in a series of broad irregular belts with a general northwest-southeast trend. The series includes sandstones, shales, limestones and intergradations of these three types. There are no eruptive rocks to break the sedimentary succession and very little faulting and comparatively little warping have occurred to rupture or deform the beds. In age the strata range from Upper Cambrian to Upper Cretaceous, with the

older rocks exposed in the northeastern part of the state and the younger ones to the west, southwest and south. From their outcrops the strata have a general dip toward the southwest of about ten feet per mile, hence the older beds lie within reach of the drill over most of the state, exception being made of the northwest corner, where some of them are absent, and of the southwest, where search for them is hardly practicable. Exception should be made also of the disposition of the Upper Cretaceous beds in western Iowa, which instead of being arranged conformably with the older strata of that region lie upon the upturned eroded edges of these older beds. The entire series of sedimentary rocks rests on a substructure of quartzite, known in Iowa as the Sioux quartzite, which is practically impervious to water and hence marks the lowest limit of efforts to obtain supplies in wells. Its surface forms a great trough which rises above the newer strata in the northwest township of the state, is 1600 feet deep or more in the north-central counties and is 750 feet below the Mississippi in the northeast corner of Iowa. Wells in central Iowa do not reach it at 3000 feet.

WATER BEARING BEDS

The limestones, of course, are water-bearing and yield generously when a crevice or a channel is reached by the drill, but the most reliable aquifers are the great sandstones, including the Jordan, Dresbach and underlying sandstones of the Cambrian and the New Richmond and St. Peter of the Ordovician. These beds have a large area of outcrop in the adjoining parts of Iowa, Wisconsin, and Minnesota, they also have a very wide distribution under the younger rocks beyond the area of their outcrop and their physical characters are such as to enable them to carry enormous volumes of water under considerable head and under conditions of exceptional purity. These characteristics give the sandstones such high favor that over probably three-fourths of the state they are sought as the ultimate desiderata where deep-lying supplies are required. Flowing wells are obtained along the Mississippi as far south as Keokuk, but under the higher lands of the interior the head is insufficient in most cases to bring the water to the well curb. At New Albin in the northeast corner of the state the Jordan sandstone rises 966 feet above sea level while at Des Moines, the farthest southwest at which it has been reached, it is 1546 feet below sea level. The distance from the

Jordan to the New Richmond is about 175 feet while the St. Peter lies about 150 feet above the New Richmond. The Dresbach and underlying sandstones are at least 500 or 600 feet thick. The Jordan averages about 100 feet, the New Richmond 50 and the St. Peter nearly 100 feet in thickness, thus assuring an abundant water-containing volume.

The foregoing summary may serve to give a generalized impression of the ground water situation in Iowa and furnish the background for a study of the depletion of ground water resources. That there has been a depletion of these resources since settlement began is a matter beyond question the difficulty lies in determining the causes and the amount, as well as the remedy.

McGEE'S STUDY OF WELLS

An investigation into the relations of wells and subsoil water was made in 1910 by W. J. McGee, a native of Iowa, who at that time was in charge of Soil Water Investigations for the U. S. Bureau of Soils. This investigation covered all of the United States, but only Iowa will be considered here.[3] Illinois, Indiana and Iowa were classed as having the most dependable records.

The 99 counties of Iowa were represented by 517 reporters, who sent information about 1527 wells, the highest number reported from any state except Missouri, which had the same number. Besides information about the locations and ownership of the wells the reporters were asked for data as to the character of wells, dates of making, and original and present depths of water in the wells. McGee divided the wells upon which reports were made into shallow or dug and deeper or drilled wells, excluding flowing wells and those of great depth. The summarized data for the two classes of wells were tabulated and arranged as in table 1.

GROUND WATER LEVELS

A number of the reporters remarked that the water level had not changed much in the preceding 20 years, that is since 1890. Some observed that there had been little change in 40 or 50 years, others that some springs and wells gave better supplies than formerly. But most observers reported that the general water level had lowered so much that, whereas the settlers and early residents had obtained

[3] United States Department of Agriculture, Bureau of Soils Bulletin, 92.

sufficient water from dug or bored wells 10 to 30 feet deep, now nearly all the wells within the reporters' knowledge were drilled—to depths of 60 to 100 feet, or some to 200 and 300 feet. In his own summary McGee states: "To one familiar with the state since the settlement of the eastern counties (as he was) the records and remarks jointly indicate a mean lowering of the subsoil water level during an average of 50 years that can hardly be put at less than 20 feet." However, as an average of the wells reported to him McGee estimated 12.5 feet as the lowering during the preceding half century. For the typical agricultural states McGee states that "the average lowering since settlement would appear to be no less than 9 feet, i.e., from well within to about the limit of capillary reach from the surface."

TABLE 1

McGee Classification of Wells

	SHALLOW		DEEP		AVERAGE
	Number		Number		
Date of making	768	1875	535	1895	1887
Depth of well, feet	895	36.1	632	153.0	
Original depth of water	749	15.4	506	77.8	
Present depth of water	852	11.8	551	74.4	
Rise	20	4.17	7	8.93	5.41
Fall	373	6.71	128	14.30	8.65
Depth to water table	895	24.1	607	78.7	46.1

CAUSES OF LOWERING

In discussing the causes of the lowering water table McGee dismissed a lessened rainfall as being negligible and unproved. Industrial causes such as tile and open ditch drainage, large wells, mining, etc., are of only local and rather superficial importance, as is consumption by animals and men. The greatest amount of lowering—amounting to 80 or 90 per cent—McGee assigns not so much to consumption of accumulated stocks as to the cutting off of the natural source of supply—the fact that under present conditions of cultivation storm waters do not enter the ground, but run off to the streams and so are unable to replenish the stores of ground water. The remedy, McGee points out, is to make each farm take care of all the water falling on it during the entire year by retaining this water by means of

mulch or well-tilled soil or contour furrows and ridges so that it will be forced to pass into the ground.

STUDIES BY UNITED STATES AND IOWA SURVEYS

For a number of years prior to 1910 the Iowa and United States Geological Surveys had coöperated in a special study of underground water conditions in this state and in the prosecution of this study every county in the state had been visited. While the collection of statistical data on the general ground water level was not the main object much information was gathered and in many of the reports on the various counties statements are made regarding the head of water. A few citations will tell the tale of changing conditions.[4]

The pioneer wells of a flowing field in Bremer county were sunk more than 30 years before and the head of a number has diminished. The static head of some wells on the hill slopes has been so drawn down that they have ceased to flow, but the supply is still ample on the bottom lands. On the open prairie of Buchanan county some of the early settlers obtained water by wells ending in pockets or streaks of gravel in the Kansan drift. Nearly all of these wells were abandoned long ago. In Cedar county the shallow wells, which at an early date found plenty of water at the base of the loess in ashen silts and basal sands, have been generally either abandoned or sunk deeper. Many of the older wells in Iowa county were dug or bored a short distance into the drift, but at present many drilled wells range in depth from 50 to more than 300 feet, ending in sand and gravel interbedded with or immediately below the drift. At Fairfield in Jefferson county shallow wells must now be bored 10 to 15 feet deeper than formerly. Ground water beneath the level prairies of Keokuk county stands high. The basal silts and sands of the loess yield sufficient for house use. Most of the water supply of Lee county is still drawn from the drift, but an increasing number of wells in recent years have been drilled to the water beds of the country rock. The Wisconsin drift of Cerro Gordo county is so imperfectly drained that where it occurs the ground-water table is near the surface. Elsewhere the Iowan drift is too thin and too well drained to be a reliable aquifer. The sandy base of the loess of Marshall county was formerly an important aquifer but drainage and cultivation have reduced the

[4] Iowa Geological Survey, vol. xxi; U. S. Geological Survey, W. S. Paper, 293.

ground-water level far below it. Wells in Adams county have been deepened to the sands at the base of the drift and the same is true of Cass county wells. In general less is said about lowered water levels in the area of the Wisconsin drift than in regions of older drift, more mature topography and better natural drainage, although even here a progressive lowering has been noted.

STUDY OF DEEP WELLS

Ever since the inception of its work the Iowa Geological Survey has made the study of underground water resources and conditions a major line of effort. Some of the results of this study of drift wells have been noted. The investigation of the deeper, artesian wells drawing water from the great rock aquifers is attended with less definite and satisfactory results. One can state in many cases that the head has declined, but the reasons are more obscure and one can not always assign changing conditions to stated causes. However, the facts may be stated even though definite conclusions can not be drawn.

In the northeastern counties, where the Ordovician and Cambrian sandstones lie not far beneath the surface, flowing wells are common in the deeper valleys. Many of these still flow, but the head of the Lansing well has fallen 15 feet and the yield has decreased from 700 to 300 gallons a minute. Many of the wells of this region have been allowed to flow unrestrainedly for years, virtually wasting the stores upon which they were continually drawing. A similar lowering of head was noted at McGregor. Dubuque has a number of deep wells, some of which reach the Jordan, some the underlying Dresbach and some still deeper sandstones. A number of these have suffered diminished flows, from all water-bearing horizons. In some cases the loss is attributed to deterioration of casings, in others to the local effects of nearby wells and in others to general lowering of static head, due to overdraft.

SOME CASES OF LOWERING

The Davenport artesian field has shown from the beginning a progressive loss of pressure, lowering of static level and diminution of discharge. This has been especially notable in the case of wells drawing chiefly from the St. Peter. The head of the Jordan and lower waters remains higher than that of the St. Peter and it is evident

that the latter bed is at least locally overtaxed. The head of the Witt's Bottling Works well has fallen from 81 feet above curb to 6 feet below curb and the yield from 300 to 20 gallons per minute.

Two of Cedar Rapids' city wells have been abandoned owing to the increased cost of pumping caused by the lowered static level and the well of the Burd Creamery Company at Council Bluffs has had the same history. The head of the Bloomfield city well has dropped from 130 to 172 feet below curb, although the yield remains the same. The head of the West Liberty city well has fallen from 9 feet above curb to 23 feet below, but the yield has increased from 120 to 250 gallons per minute. There have been no repairs. The head of one deep well at Washington has dropped from 44 to 133 feet below curb while the head of another rose from 100 to 70 feet below curb.

Dr. W. H. Norton, our underground water expert, has compiled a list of pairs of neighboring wells which shows their hydraulic gradient and the actual differences in head of water. With Doctor Norton's consent this list is incorporated in table 2.

A study of table 2 shows a number of incongruities. For instance, the hydraulic gradient between Green Island and Preston is about level, yet the head at the latter town is 24 feet lower than that at the former. Between Vinton and Garrison the gradient is level, but the head at Garrison is 38 feet above that at Vinton. The gradient from Sabula to Delmar is upward and the head at Delmar is 78 feet higher than at Sabula. The gradient from West Liberty to Oakdale sanatorium is upward, but the head is 27 feet lower at Oakdale. The gradient from Washington to Winfield is downward and the head at Winfield is 74 feet lower than at Washington. In all cases where the hydraulic gradient is normally downward the head is lower, but in cases where the gradient is normally level or upward the head seems to be independent of the gradient; in some cases it is higher, in others lower. These differences may originate in part in the different sources of the water in the contrasted wells. The elapsed time between the drilling of these pairs of wells ranges from 9 to 66 years.

These records as well as many others at hand seem to show that a variety of causes has been effective—some of them evidently conflicting. Deterioration of casing, local clogging of the water-bearing beds, interference of nearby wells, filling of the bore hole, leakage into the surrounding strata, these are some local causes which would tend to diminish the supply and lower the head. In some cases the

field is really being overtaxed, at least that portion of it near the wells. Whether the entire artesian field is being permanently overdrawn can not be told without intensive study of the relation between the supply and the demand.

RECENT INVESTIGATION OF GROUND WATER

When I was asked to prepare this paper I enlisted the coöperation of the United States Weather Bureau and the Weather and Crop Bureau of the Iowa Department of Agriculture in circularizing crop reporters and well drillers to obtain recent data on wells and ground water. Between 650 and 700 letters were sent out asking for information about the location of wells as to county, township and section; character, whether dug, bored, driven or drilled; whether in valley, hillside or upland; dates of making; depth; original and present depths to water and of water; and owners. The response to this inquiry is thus far by no means complete, but some general impressions may be formulated from the replies received to date. The effect of the rains of recent months has been to raise the water level in shallow—dug or bored—wells very markedly. On the other hand, a number of correspondents state that the deeper drilled wells are not notably affected by rainy or dry seasons. A number of men say that, whereas in early days, dirt wells, dug or bored, were sufficient, these later became unequal to the demands made on them and wells were deepened, either in unconsolidated materials or in many cases into rock. More recently dug wells are becoming scarcer and scarcer in some localities and reliance is being placed much more on drilled wells. Conversely, others state that there has been no appreciable change during their lifetimes. Some state that ponds and springs have disappeared, others that springs are as numerous as in former years. This may be due to recent rains or to especially favoring topographic and geologic conditions. Where a lowering of water level in wells is noticed it is variously attributed to tile and ditch drainage, in so far as shallow changes are concerned, to greater demands from a vastly increased amount of stock, to local causes such as clogging of the aquifer, overdrafts on individual wells or to the exhaustion of sand or gravel beds which had supplied wells. One driller states that since Nishnabotna river, in Pottawattamie county, was dredged and straightened the water level in wells has lowered 15 or 20 feet as much as 2 miles back from the stream.

TABLE 2

Data on deep wells

Location	Date of completion	Direction of new well from old	Distance	Hydraulic gradient from old to new*	Original head	Footing	Recession (−) or advance (+) compared with control well	Number of years elapsed
			miles					
Green Island, C. M. & St. P. Ry.	1902				665	Prairie du Chien		
Preston, city well	1922	SSW	8	=	641	Jordan	−24	20
Sabula, city well	1895				652	Jordan or below		
Delmar, C. M. & St. P. Ry.	1917	SSW	22	+	730	Trempealeau	+78	22
Clinton, Water works	1886							
Nos. 1 and 3	1890				632	Franconia and Eau Claire		
DeWitt, city well	1923	W	18	+	617	Eau Claire	+15	33
Vinton, city well	1889				800	Prairie du Chien or Jordan		
Garrison, Canning Company well	1926	WSW	7	=	838	Prairie du Chien?	+38	37
Belle Plaine, city well	1907				776	Prairie du Chien		
Van Horne, C. M. & St. P. Ry.	1916	NE	12	=	783	St. Lawrence	+7	9
West Liberty, city well	1888				705	Trempealeau. St. Peter head, 676		
Oakdale, Sanatorium	1919	WNW	20	+	678	Shakopee	−27	31

Homestead, city well	1895				751	Dresbach?		
North English, city well	1921	SSW	20	–	719	Cambrian?	–32	26
Washington, city well	1891				694	Jordan		
Brighton, city well	1923	SW	11	=	658	Oneota	–36	32
Winfield, city well	1921	SE	19	–	620	Shakopee	–74	30
Keokuk, Hubinger well	Before 1889				667	Cambrian		
Donnellson, city well	1925	NNW	19	+	616	Shakopee	–51	36
Mount Pleasant, Hospital well	1862				689	Saint Peter		
Morning Sun, city well	1923	NE	19	=	623	Shakopee	–66	61
Somers, city well	1904				1097	Galena-Platteville		
Gowrie, city well	1926	SE	9	–	1058	Shakopee	–39	22

* + Hydraulic gradient normally upward from old well to new; = about level; – downward.

CONCLUSIONS

I believe that we are justified by the evidence at hand in drawing these conclusions: With regard to the shallow types of wells, dug or bored especially, in general these have become scarcer with the passing years because the supplies of water within their reach have gradually been depleted, partly by increased consumption by animals, by increased transpiration by cultivated crops, by open and closed drains, and partly by increased runoff of rainfall from cultivated areas. However, some parts of the state do not seem to have suffered from this lowering, perhaps because conditions are not so favorable for natural drainage and so the soil water is retained to a greater extent. Driven wells still find plentiful supplies because they are made as a rule in valleys with gravel strewn floors, which are less affected by changing conditions than are upland areas.

As to drilled wells, those of moderate depth as used on farms or smaller municipalities have gradually been deepened into the lower strata of the drift—many drillers speak of top water in yellow clay and lower water in blue clay, with another horizon in sand at the base of the drift. In parts of the state having thinner drift drilled wells now enter the stratified rocks, some for a few feet, many for a greater distance. Most wells of this class range in depth between 100 and 200 feet, although some are as deep as 400 and 500 feet. Since these wells draw their supplies from the general body of ground water rather than from the shallower soil water fed by recently fallen rains, their gradual deepening in the wake of the constant lowering of head seems to point rather conclusively toward a real lessening of the amount of water in the ground, owing to both increased demand and decreased supply. In some localities this lowering of head amounts to 20 feet or more during the present century, according to the reports of several drillers, and the total lowering from the time of settlement must be much more than this amount. However, other drillers state that they see little or no difference in ground water conditions while they have been drilling and of course those local factors which affect shallow wells would have some, though less, influence on wells of this type. Again, while shallow wells fluctuate with the seasons and respond quickly to periodic variations in rainfall, deeper wells show much less change from season to season and year to year.

Finally, as to the deep artesian wells which seek out the great

aquifers of the stratified rock series, the evidence so far obtainable seems to be far from conclusive or even consistent. Some of these wells have suffered diminished yields and lowered heads, some of them headed lower from the start than did earlier wells in the same region. But some have higher heads than would be expected from the known factors and a few report higher heads or greater yields than formerly. Unfortunately for purposes of study these wells are not spaced closely enough for us to say definitely whether or not the general level or the amount of water has receded or remained the same, or, in other words, whether such changes as have occurred are due to local or to widespread causes. Of course, the deeper a well is the greater is the available radius from which it may draw its supply and the greater its chance of surviving drought or draft. Therefore, these deep wells as a class will always have a large assurance of permanence even in the face of the unfavorable factors.

AEROBIC SPORE-FORMING BACILLI WHICH FERMENT LACTOSE

By Stewart A. Koser[1] and Winifred C. Shinn[1]

The presence in water supplies of aerobic spore-bearing bacilli which ferment lactose has been reported several times. It is now recognized that these types may cause some confusion in interpreting results in the standard lactose broth, especially when examining treated waters. The confusion caused by anaerobic lactose fermenters, such as the Welch bacillus and its allies, has been well recognized for a considerable time, but the recognition of aerobic forms which may also give rise to misleading presumptive tests has been more recent.

From the reports which have appeared thus far it would seem that the aerobic forms are rather widely distributed throughout the country. Meyer (1918) found one of these types in the water supply of Newport, Kentucky upon several occasions. Ewing (1919) isolated from Baltimore drinking water an organism which he believed to be identical with that of Meyer. Other organisms apparently more or less similar were encountered by Perry and Monfort (1920–1921) in several Illinois waters, by Hinman and Levine (1922) in Iowa, by Lisk (1923) in a sample of milk from Florida and by Schreiner (1927) in chlorinated waters in Kansas. In addition, several others have noted their occurrence but did not describe the cultures. Thus, Havens and Dehler (1923) reported the finding of aerobic spore-bearing bacilli which fermented lactose in the intestinal tract of the top minnow in Alabama. Hall and Ellerson (1919) found them in California, Raab (1923) encountered them in the treated water at Minneapolis, though he states that they appeared rarely, and Ruchhoft (1926) has noted their presence in Lake Michigan water. In view of the practical importance of these forms Norton and Weight (1924) studied their distribution in the vicinity of Chicago. From 438 various sources 25 cultures were obtained. The highest proportion of positive findings was from animal manures, garden soil, and root and vegetable washings. Cultures were also obtained, though less frequently, from water supplies, dirt, street washings, and so forth.

The present observations are reported since they may add something to our knowledge of the distribution and occurrence of this group of bacilli as well as furnish a description of several types re-

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cently encountered in Illinois. During the course of an examination of soil samples for members of the coli-aerogenes group (Koser, 1926) a number of these spore-forming lactose fermenters were found. The soil samples were taken at random from cultivated fields and pastures throughout the east central part of Illinois. In all, 52 samples of soil, mostly from cultivated fields, were examined both by enrichment cultures in lactose broth and by direct plating in Endo medium. Varying quantities of each sample were subjected to examination so that some idea of the relative abundance of the organisms could be obtained.

Aerobic spore-forming lactose fermenters were encountered in 23 of the 52 soil samples. From the 23 samples which showed their presence 64 cultures were isolated. The distribution of these forms in soil appeared to be rather irregular. In some instances 5 or 10 gram samples yielded negative results, while in others they were obtained from surprisingly small amounts, often from dilutions representing 0.01 or 0.001 gram of soil. In some places they are fairly abundant and it seems altogether reasonable that they may be washed into water supplies in fairly large numbers.

For purposes of comparison several other cultures of spore-forming lactose fermenters were obtained from other laboratories. These included 6 labelled B. macerans, 4 of which were described by Hinman and Levine (1922), one was from the type culture collection at the McCormick Institute and one from the University of Wisconsin. Also, one culture of those described by Norton and Weight (1924) was included and finally one labelled B. asterosporus from the type collection.

Study of the morphology, cultural and biochemical characteristics led to the conclusion that our own cultures fell into at least two distinct groups, with several minor variations. Of the entire 64 cultures, 57 appeared quite similar and for convenience have been referred to here as Group I. This group is significant from the water analysts' standpoint for they appeared to be rather common in soil and in some samples were undoubtedly present in rather large numbers. It seems certain that they would be washed into water supplies. The remaining seven cultures are apparently quite rare. All seven were obtained from one sample of soil and they were not encountered again. As will be pointed out later, there is some uncertainty whether these seven cultures should be classified as spore-formers. The description of the Group I cultures, which comprised the majority of those found, follows.

GROUP I

Microscopic appearance and staining. In twenty-four hour agar slants the rods are 2.0 to 4.0 microns long by 0.7 to 0.8 wide. In plain broth and in lactose broth the length was somewhat greater, usually from 5.0 to 8.0 microns. Gram stains were made from young agar slants and compared with known positive and negative controls. They were regarded as being Gram-positive. Several previous workers have placed these organisms or closely related types in the Gram-negative class, adding that the violet stain was removed with difficulty and that the interpretation might be easily confused. All cultures stained readily with the ordinary dyes. In some of the preparations a capsule-like halo could be seen. A tendency to granulation was noted, especially when grown in lactose broth.

Spores. In agar slant cultures these appear usually in two to four days. Considerable variation was noticed in the different cultures, some forming spores much sooner and in greater numbers than others. Spore formation was usually retarded in plain broth and in lactose broth. The spores are large, oval, much wider than the rod and their position in the rod varied from central to subterminal. They usually do not remain attached to the rod so that upon microscopic examination the free spores are usually seen.

Motility. This was observed in beef extract peptone broth, using cultures eighteen to twenty-four hours old. They were classed as motile. In all cultures some very active rods were seen while others in the same field exhibited little if any motility.

Colonies. On nutrient agar the colonies are small, 1.0 to 1.5 mm. in diameter, white, with somewhat irregular edges and a fairly smooth surface. When touched with the needle they show a tendency to adhere to the agar.

Endo medium. After twenty-four hours at 37°C., the colonies are small and deep red, about 1 to 1.5 mm. in diameter. They are considerably smaller than the average colon-group colony at this time. After thirty-six or forty-eight hours the colonies are slightly larger and the color is very deep red with a suggestion of metallic lustre in some cases. The surface is slightly raised and rather rough. In most cases the roughness took the form of fine irregular wrinkles, though in a few cultures it approached the concentric ring type. The margins are undulate or in a few cases very irregular approaching the ameboid type. The colonies are sticky and cling rather tenaciously to the surface of the medium when touched with the needle.

The most striking features of the colonies which would serve to separate them readily from Bact. coli or allied forms are the smaller size, the rough surface and their tenacious adherence to the medium.

Eosin-methylene blue plates. An interesting inhibition of growth occurred. After twenty-four hours colonies are either invisible or else barely discernible as minute pin-points. After several days incubation the colonies are slightly larger and appear as small dots, usually colorless. The inhibition of growth by this medium is quite striking and held true for all of our cultures of this type as well as for the other more or less similar spore-formers obtained from other laboratories.

Agar slants. On plain nutrient agar the growth is very scanty, filiform,

flat, dull white with usually a rather smooth surface and adheres somewhat to the medium though this stickiness is not nearly so pronounced here as on the Endo medium.

Nutrient broth. Growth appears first in young cultures as a diffuse turbidity, after forty-eight hours it is more or less flaky to granular, gradually settling to the bottom.

Lactose broth. Gas is apparent within twenty-four hours at both 30° and 37°. The amount in the inner tube varies from a small bubble to 25 per cent and after forty-eight hours is usually 25 to 50 per cent. There is a decided tendency here to formation of a flaky or stringy viscid growth rather than a diffuse turbidity. This characteristic appeared to be somewhat more pronounced at 30° than at 37°.

Litmus milk. An acid curd is formed within forty-eight hours, gas production is also evident with more or less distortion of the curd which is riddled with gas bubbles. In many cases this approached the stormy fermentation so characteristic of the Welch bacillus, though it varied considerably with different cultures and even with the same culture on repeated tests. This appearance was then followed by gradual peptonization or digestion of the curd. After a week or ten days the tubes are filled with a clear straw-colored fluid with some soft, partially digested curd in the bottom or clinging to the sides of the tube.

Gelatin. At 20° to 25°C. complete liquefaction occurred in almost every instance within six days. The Bacillus macerans cultures received from Iowa which were run for comparative purposes were negative at 6 days but showed some liquefaction after two weeks.

Fermentation and other biochemical tests. Acid and gas were produced from the following: Dextrose, levulose, galactose, lactose, sucrose, maltose, raffinose, arabinose, dextrin, inulin, salicin, mannite, and glycerol. In some cases gas production was delayed and appeared only after seven to fourteen days, though acid was evident after the first twenty-four to forty-eight hours. This was true especially of levulose, galactose, maltose, dextrin, inulin, salicin, and mannite. Negative results were secured with dulcite.

Formation of indole could not be detected by the Goré test in four day cultures in Witte peptone solution or casein digest medium. Nitrates were reduced to nitrites. Starch was digested. Hydrogen sulphide tests with lead acetate agar were negative.

Differential tests. The methyl red, Voges-Proskauer and citrate tests which have been recommended for differentiating members of the coli-aerogenes group were applied to these cultures, though it should be realized that these tests may have little significance when applied to a group of bacteria other than that for which they were originally designed. In the standard peptone-dextrose-dipotassium phosphate medium of Clark and Lubs the methyl red test was found to be negative while the Voges-Proskauer test was usually positive. A few cultures gave both negative methyl red and Voges-Proskauer tests. In the citrate medium (Koser, 1924) the cultures were unable to develop and the tubes remained clear in every case.

Anaerobic growth. Under the conditions secured with pyrogallol and NaOH in Wright tubes, these cultures developed readily on dextrose agar slants.

Control cultures of Bacillus cereus showed a scanty growth after forty-eight hours under similar conditions. In dextrose broth under vaseline seal development was as rapid as in open tubes. Gas formation was evidenced by the forcing up of the vaseline seal.

Heat resistance tests. Spore suspensions prepared from agar slant cultures survived ten-minute heating periods at 80°C. and at 90°C. After heating for five minutes in the Arnold (about 97° to 98°C.) negative results were obtained in some cases. Unheated control suspensions gave good growth in each case.

Brilliant green bile. Tests were made of the ability of the spore-forming lactose fermenters to develop in green bile media. A number of experimental green bile combinations were tried.[2] These were of the same composition as those used by Dunham and Schoenlein (1926) in their work with Bacterium coli. In addition to 1 per cent lactose and 1 per cent peptone the various lots contained 2 per cent oxgall with concentrations of brilliant green ranging from 1:15,000 to 1:100,000 and 5 per cent oxgall with concentrations of the dye ranging from 1:10,000 to 1:30,000. Controls with peptone, lactose and oxgall but without the brilliant green were also used.

Negative results were secured in every case, not only with our own cultures but with those received from other laboratories. The inhibition of growth was quite striking in comparison with control tubes of standard lactose broth and even though incubation was prolonged for a week or more,—a period far longer than that used in water examination,—no growth resulted. It is also noteworthy that there was no growth in the lots which lacked the brilliant green. Evidently inhibition is due to the oxgall rather than the dye.

OTHER LACTOSE FERMENTERS

In addition to the cultures described above a few others were encountered. As pointed out before, these were found but rarely and only 7 out of a total of 64 cultures fell into this lot. There is considerable doubt as to whether these 7 cultures should be classed as spore-formers and perhaps they should not be included in this report. They were all peculiar in that when stained with carbol fuchsin or other common dyes colorless oval areas could be seen in some of the rods and the appearance resembled somewhat that of a spore-forming culture. However, suspensions made from these cultures were not heat-resistant. Since resistance to higher temperatures is usually regarded as one of the fundamental properties of bacterial spores it would seem that these organisms should not be considered as spore-formers. However, they will be briefly described here since they represent a type of lactose fermenter distinct in some respects from the coli-aerogenes group.

[2] These experimental media were kindly supplied by H. G. Dunham of Digestive Ferments Company.

All seven cultures were quite similar. When taken from twenty-four hour agar slants the cells appear as short thick rods. They occur singly or occasionally in pairs. Capsules were frequently seen, especially in stains made from milk cultures. The oval colorless portion resembling a spore was rarely seen in cells from young agar slant cultures but was evident in cultures three or four days old. The "spores" appeared to be central or subterminal. The vegetative cells stained readily with the usual dyes while the Gram stain was clearly negative in all cases.

On Endo plates the appearance of the colonies varied somewhat with the temperature of incubation. At 30°C. colonies are large, circular, convex, quite viscid or sticky and of a deep pink or deep red color. They usually present a very watery appearance and adjoining colonies have a tendency to run together. At 37°C. the sticky viscid characteristics are lost and the colonies are then rather flat, butyrous and deep red. On eosin-methylene blue plates the growth was not restrained as in the case of the Group I cultures. Colonies developed as readily as on Endo plates and resembled rather closely the typical Bact. aerogenes colony.

An abundant white glistening filiform growth is formed on agar slants. After two or three days this becomes distinctly sticky and stringy. Older cultures gradually lose the watery mucoid characteristics. They become drier in appearance, finely wrinkled and at the same time a light yellow pigment appears. After two or three weeks the growth is wrinkled, yellow, rather tough and hard to separate from the agar slant. Upon continued cultivation on agar in the stock collection some of the cultures have shown a tendency to lose the extremely mucoid type of growth which they exhibited when first isolated.

In lactose broth fermentation with gas production appeared to take place more readily at 30° than at 37°. At the higher temperature growth was always apparent as a light turbidity after twenty-four hours, though gas production was not in evidence until forty-eight hours or occasionally longer. At 30° development was slightly more rapid and gas production was evident within twenty-four hours. The growth in lactose broth becomes more or less viscid or stringy. This was especially marked with some of the strains at 30° but not at 37° and the appearance of the mucoid stringy type of growth seemed to be dependent on the temperature of incubation.

Gelatin was completely liquefied in about six days. In litmus milk there was an acid reaction with ropiness. In some cases an acid curd was formed after four or five days incubation. No digestion of the curd was noted. Tests for indole in suitable media were negative. Hydrogen sulphide was not produced in lead acetate agar. Starch was not digested. Nitrates were reduced to nitrites. Acid and gas were produced from dextrose, levulose, galactose, lactose, sucrose, maltose, raffinose, and arabinose. Slow acid production without gas occured in dextrin, salicin, glycerol, and mannite. Inulin and dulcite gave negative results.

Methyl red tests were negative and the Voges-Proskauer reaction was positive. Growth occurred in the citrate medium. In respect to these differential tests these organisms were quite similar to Bacterium aerogenes. It is perhaps noteworthy that the colony on Endo or eosin methylene blue medium

was also quite similar to that of Bacterium aerogenes. Brilliant green bile failed to exert a restraining effect upon these organisms, as it did in the case of the Group I cultures. Upon inoculation into brilliant green bile gas formation occurred readily.

Heat resistance. Suspensions made from four to nine days old agar slants were subjected to various temperatures for different lengths of time with uniformly negative results. Even an exposure to 70°C. for ten minutes killed all cells. Bacillus cereus and several of the spore-formers of Group I which were run as controls survived moderate heating periods readily while these cultures were killed.

DISCUSSION

A review of the published reports of others together with a comparative study of the cultures received from Iowa, Chicago and other sources leads to the conclusion that the Group I cultures described here are quite similar to those reported previously by others. The culture received from Norton and the description by Norton and Weight (1924) both showed a very striking resemblance to our own cultures and it seems probable that they are the same. With the exception of a few minor differences our cultures also closely resembled the descriptions given by Meyer (1918) and by Ewing (1919).

A few points of distinction were noticed between our Group I cultures and those received from Iowa. The vegetative cells of our cultures were slightly shorter and heavier than the several Iowa cultures used for comparison. Also, our cultures liquefied gelatin much more speedily. On Endo medium the colonies were larger and, with a few exceptions, the edges not as irregular or lacerate on those of the Iowa cultures. In litmus milk the Iowa cultures produced acid but no curd, whereas our cultures produced a curd which was more or less torn due to gas production. Hinman and Levine believed their cultures to be identical or very similar to the Bacillus macerans of Schardinger (1904). Our cultures, while similar in some respects, could not be considered identical with the Iowa cultures.

The culture described by Lisk (1923) also resembles our Group I cultures, especially in regard to agar colonies and the deportment in litmus milk. On the other hand, there were several minor differences, such as the speed of gelatin liquefaction. Lisk considered her organism to be identical or very similar to the Bacillus asterosporus described by A. Meyer in 1897. The early description of this organism given by Migula (1900) and the later one by Bergey (1925) leave one in doubt as to whether or not it was a lactose fermenter. Chester

(1903), however, has given a description of a culture which was received from Kral's laboratory. He states that it fermented lactose with production of acid and gas and that milk was coagulated in about 10 days. Apparently the B. asterosporus of A. Meyer is fairly common in soil for it was noted by a number of the earlier German investigators. Bredemann (1908), especially, isolated it from soil samples collected in various parts of the world. He states that the organism grows readily in nitrogen-free media and has the power of nitrogen-fixation. The ridged appearance of the spores, said to be characteristic of B. asterosporus, was not noted in our study nor was it observed by Lisk. It is difficult to determine whether our Group I cultures should be classed as Bacillus asterosporus.

These various reports, taken in connection with our own work, indicate that at least several different species of aerobic spore-bearing bacilli capable of fermenting lactose have been encountered in this country. The different types appear to be more or less similar and they are evidently closely related. From the standpoint of the practical water analyst they may be considered as a group. Thus far, all the available evidence shows that they are not significant indicators of pollution and their chief importance resides in the fact that the fermentation of lactose which they produce may be confused with the presumptive test for the coli-aerogenes group. If the existence of such forms is clearly recognized by the water analyst it should be possible to guard against them, either by following through the confirmed procedure of the Standard Methods or perhaps by the use of special bile or dye combinations.

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BRILLIANT GREEN BILE FOR THE DETECTION OF THE COLON-AEROGENES GROUP

By Harry E. Jordan[1]

The previous work on this matter by members of this Committee was detailed in this Journal (vol. 4, no. 6).

The use of brilliant green bile has also been recorded by Howard, Ruchhoft and Lauter.[2] An article "Gas Production by Bacterial Synergism" by Holman and Meekison[3] has a decided bearing upon the errors to which the present standard methods are subject.

As was indicated in our previous communication, it appeared wise to study the use of brilliant green bile as an interpolated step in the present procedure to learn if such modified procedure might be found an improved substitute for the present confirmed test. Dunham and Levine studied the bile-brilliant green ratio and suggested that the co-workers use two materials:

1. A medium in which the inoculum would grow in a 5 per cent bile with a 1/20000 density of brilliant green.

2. A medium in which the inoculum would grow in a 2 per cent bile with a 1/75000 density of brilliant green.

The reaction of both media after sterilization was pH 7.1 to 7.4. They are hereafter referred to as 5 per cent bile and 2 per cent bile.

A group of co-workers agreed to submit certain samples passing through their laboratories to special procedure as outlined in a set of instruction sheets, the essential work outlined being as follows:

1. Colon group completion—according to 1925 Standard Methods.
2. Colon group completion according to 1925 Standard Methods—except

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[2] Howard: Isolation of the colon group in water. Canadian Engineer, April 21, 1925. Ruchhoft: Comparative studies of standard methods and the brilliant green bile medium. Jour. A. W. W. Assoc., vol. 16, p. 778. Lauter: Earlier determination of Bacterium coli. Jour. A. W. W. Assoc., vol., 6, p. 625.

[3] Holman and Meekison: Gas production by bacterial synergism. Jour. Inf. Dis., vol. 39, p. 145.

5 per cent brilliant green bile is used for original planting instead of standard lactose broth.

3. Colon group completion according to 1925 Standard Methods, except 2 per cent brilliant green bile is used for original planting instead of standard lactose broth.
4. Colon group completion according to Standard Methods except that from tube of standard lactose broth—used as an original planting medium in which gas has occurred—a loopful of the active growth is to be transferred to a fermentation tube containing 5 per cent brilliant green bile—and completion carried on from this point according to Standard Methods.
5. Colon group completion as in (4) except that 2 per cent brilliant green bile is to be used instead of 5 per cent bile.

The following persons work has been summarized: Armstrong, Omaha; Berry, Columbus; Billings, Grand Rapids; Butterfield, Cincinnati; Howard and Thompson, Toronto; Kershaw and Taylor, Indianapolis; Lauter, Washington; Mahlie, Fort Worth; Marshall, Lansing; McCrady, Montreal; Nyhan and Gorman, Chicago; Raab, Minneapolis; Rider and Stroud, Tuscon; Stevenson and Herb, Sacramento and Wallace, Detroit.

In tabulating the results of the work, the basis of comparison used is the number of coli-aerogenes group completions found when the present standard method was used.

Along with this basic figure a notation has been made of the speed of gas production in completing cultures as shown by the per cent of the total number of cultures that formed gas in twenty-four hours. This has a bearing upon the problem of non-selectivity of the bile medium as shown on certain waters.

The data from all laboratories are summarized in table 1.

At this point it should be stated that there were 167 cases shown on the tabulation sheets where completion occurred in cultures handled on the bile which did not complete when standard methods were used. Several factors contributed to this. The major one was probably the element of random selection. Anyone who has handled a large number of biological growth operations is well aware that there is always the confusing element of variation in the growing power or characteristics of the individuals or groups selected for study. The element of chance has a decided bearing upon results such as are shown here.

On the other hand, the experience of Hale on the New York Metropolitan water supply is to the effect that the B. welchii type

organism will interfere with completion according to standard methods and not with material handled in bile media. This may be shown to affect at least part of the 167 non-standard completions.

Analyzing the data in table 1, we have the summation shown in table 2.

The purpose of this investigation has been stated as follows:

> For the purposes of this investigation it appeared necessary to submit a method that would give a density picture as near the standard procedure as could reasonably be attained, and at the same time clear up the confusion now existing on account of the wide divergence between original fermentations and complete colon group figures.
>
> The fundamental concept should be the need of finding every organism of this group that has any vestige of metabolic ability left at the moment of sampling, to reduce to a minimum the number of false indications, to reduce the amount of materials now wasted in standard procedure and to shorten, if possible, the interval between sampling and reasonable confirmation of the nature of the organism studied.

In the light of the above, the following facts are noted:

1. The 2 per cent bile is slightly superior to the 5 per cent both when used as the material in which to plant water samples direct as well as a subcultural medium. In both cases the relation between completions according to standard methods and the 2 per cent bile is higher than when the 5 per cent bile is used. The superiority is so slight as to leave the decision as to density subject to other considerations.

2. When the bile was used as a direct planting medium, the percentage of original fermentations completed checks with previous studies by this committee, but the 2 per cent bile shows a slightly higher degree of completion.

3. When the bile was used as a direct planting medium, no cultures were discarded because of the presence of spore forming organisms.

4. When the bile is used as a second step in a subcultural series, the degree of completion on the better bile density is 95 per cent (compared to Standard Completions). A study of table 1 will show that on a number of waters the correlation is perfect—notably in the large volume of work done by Butterfield. The greatest deviation is shown in the work by Miss Nyhan at Chicago and Mr. Taylor at Indianapolis. It is worthy of note that both these laboratories were working with a series of slow fermenting organisms. Mahlie at Fort Worth reports an abnormally slow fermentation rate, but correlates better than the two above noted.

TABLE 1

Summary—comparative tests of completion of coli-aerogenes group tests by various methods

	ARMSTRONG	BERRY	BILLINGS	BUTTERFIELD	HOWARD-THOMPSON	KERSHAW-TAYLOR	LAUTER	MAHLIE	MARSHALL	MC CRADY	NYHAN-GORMAN	RAAB	RIDER-STROUD	STEVENSON-HERB	WALLACE	
Standard lactose broth:																
Speed of gas production 24/48 hours ratio	74	80	95	78	98	48	76	9	91	76	47	74	66	77	75	73%
Coli-aerogenes group complete	44	68	53	110	81	85	20	33	50	21	35	61	44	35	44	784
5 per cent brilliant green bile:																
Gas 24 hours	25	24	50	47	64	34	12	0	33	15	19	34	24	21	34	436
Gas 48 hours	30	54	51	56	67	60	18	21	44	19	28	44	34	31	41	598
Plate growth	29	54	50	56	66	60	15	21	43	18	28	43	33	31	41	588
Secondary broth—Gas	29	50	48	55	65	58	15	15	43	16	23	43	31	31	40	562
Non-spore-former, complete test	29	50	48	55	65	58	15	15	43	16	23	43	31	31	40	562
2 per cent brilliant green bile:																
Gas 24 hours	25	48	50	52	69	52	16	1	38	17	15	52	28	25	31	519
Gas 48 hours	31	64	54	64	70	76	19	22	44	20	32	59	36	31	41	663
Plate growth	31	63	49	63	70	76	18	22	42	20	32	59	36	31	41	653
Secondary broth—Gas	31	59	48	62	69	69	18	22	42	17	31	58	36	29	40	631
Non-spore former, complete test	31	59	48	62	69	69	18	22	42	17	31	58	36	29	40	631

5 per cent bile from 3 or 4:																
Gas 24 hours	38	60	54	108	80	67	20	17	44	17	27	55	42	33	44	706
Gas 48 hours	39	66	55	110	80	77	20	33	48	20	31	60	44	35	44	762
Plate growth	39	66	53	110	78	77	20	33	48	20	30	60	44	35	43	756
Secondary broth—gas	38	63	53	110	78	73	20	33	48	19	25	60	44	35	43	742
Non-spore-former, complete test	38	62	53	110	78	73	20	33	47	19	25	60	44	35	43	740
2 per cent bile from 3 or 4:																
Gas 24 hours	38	62	54	109	80	72	20	21	44	18	28	61	44	35	44	730
Gas 48 hours	39	63	56	110	80	78	20	33	49	19	31	61	44	35	44	762
Plate growth	39	63	53	110	79	78	20	32	49	19	31	61	44	35	44	757
Secondary broth—gas	39	63	53	110	79	74	20	32	49	18	25	61	44	34	44	745
Non-spore-former, complete test	39	63	53	100	79	74	20	32	48	18	25	61	44	34	44	744

TABLE 2

	TOTAL	LOSS FROM PRECEDING TOTAL	PER CENT	TOTAL COMPLETIONS	PER CENT
Coli-aerogenes group completion according to standard methods				784	100
Coli-aerogenes group completions when water was inoculated in to 5 per cent bile:					
24-hour gas formation	436		72.7		
48-hour gas formation	598		100		76.1
Plate growth (Endo or E.M.B.)	538	10	98.2		
Lactose broth re-fermented, complete test positive	562	26	93.7		
Spores not present or few	562	0	93.7	562	71.6
Coli-aerogenes group completions when water was inoculated into 2 per cent bile:					
24-hour gas formation	519		78.1		
48-hour gas formation	663		100		84.5
Plate growth (Endo or E.M.B.)	653	10	98.6		
Lactose broth re-fermented, complete test positive	631	22	95.2		
Spores not present or few	631	0	95.2	631	80.5
Coli-aerogenes group completion when original lactose broth fermentation is reinoculated into 5 per cent bile:					
24-hour gas formation	706		92.7		89.8
48-hour gas formation	762		100		97.2
Plate growth (endo or E.M.B.)	756	6	99.3		
Lactose broth re-fermented	742	20	97.5		
Spores not present or few	740	2	97.1	740	94.4
Coli-aerogenes completion when original lactose broth fermentation is reinoculated into 2 per cent bile:					
24-hour gas formation	730		95.8		93
48-hour gas formation	762		100		97.2
Plate growth (Endo or E.M.B.)	757	5	99.3		
Lactose broth re-fermented	745	12	97.7		
Spores not present or few	744	1	97.6	744	95

5. In three cases out of 1487 cultures, the presence of spores was noted by the worker and used as the basis of rejecting the completion. This is a frequency of 0.2 per cent and appears to be unimportant. The question of the interference seems to be answered in a practical manner.

The writer wishes to express his cordial appreciation of the work done by his associates in this project. This method of studying the merits of proposed changes in methods has demonstrated its efficiency. Appreciation is also expressed for the assistance of Dr. Dunham of the Digestive Ferments Company, who prepared and furnished free of charge all the special bile-brilliant green media used in the work.

Before suggesting final conclusions, it seems worth while to offer certain observations concerning present standard method procedure.

It will be remembered that in 1912, standard practice was modified to use a "bile" medium as the original inoculation medium. In 1917, it was modified to use lactose broth instead. Prior to 1912, dextrose broth was used. Both the earlier materials came to be recognized as imperfect. But at the present time, while a number of workers recognize the limitations of the present standard practice, there is a certain tendency on the part of others to overlook defects.

Putting the objections briefly, they are as follows:

1. The complexity of growth in lactose broth is often so great as to make the isolation of colon group organisms difficult.

2. Synergism is responsible for a very large number of cases in which gas is produced, but no plate growth follows. On water supplies where this occurs, the "presumptive" test is recognized as having little significance.

3. The diagnostic value of Endo or E.M.B. plate growth varies materially in waters of different degrees of pollution. It appears that in waters not freshly polluted where synergistic growths are frequent the picture that the plate affords is less useful than in freshly polluted waters.

4. Many laboratories appear to carry on completion subcultures from a plate on which the growth is massive and mixed rather than from a more sparsely planted plate on which the colonies are well separated and distinct.

These objections have a bearing upon the validity of this project. We have accepted the 784 completed tests as correct, and have required that the alternate methods approach or check with this

figure. Does anyone know that this is or is not a true picture? The answer must be that there are probably cases of synergism included in the 784 total, but that no definite statement can be made as to how great this error is. We must even extend our criticism in part to the brilliant green bile for there are 80 cases shown in table 2 when fermentation has occurred in brilliant green broth and plate growth occurred but there was a failure to obtain re-fermentation in lactose broth. There is that degree of non-specificity of the green bile broth which appears to permit combined growths to ferment, where the fermenting organism either died out in the broth before transplanting or was excluded by some selective action of the plate. So we must frankly admit that green bile fermentation is not limited to members of the colon group. It is worthy of note that, where fermentations are prompt, the group is present and where the fermentation rate is slow, other organisms complicate the reactions.

The study of brilliant green bile media has been carried on in many laboratories for from three to five years, in a few much longer. Many workers have adopted it in some fashion or other for use on waters in the process of purification or as an aid in rapid evaluation of finished waters. In the light of the studies with which the author has had contact, it seems fair to say that brilliant green bile offers a means of routine study that cannot be disregarded and should be written into standard methods in such a way that those who find it of value will use a procedure producing results comparable with those produced in other laboratories.

During the Chicago convention of the American Water Works Association conferences were held with Messrs. Norton, Levine, Hinman, Hale, Koser, Dunham, Langlier, Lauter, Howard, the writer and others present and, having knowledge of this study as well as others that have preceded it, the following procedure met the approval of most of the men present.

1. The Standard Method for Complete Colon Group determination should have emphasized the necessity of making Endo or E.M.B. plates with so dilute an inoculation that the colonies growing thereon are separate and distinct. The practice in many laboratories of making a heavy streak inoculation produces a growth that is of no value in the later steps of the completion process. If the microscopic examination for spores evidences a mixed culture, it should be replated and all data recorded should be from cultures as distinct as is possible to make them.

2. The group disapproves any tendency to evaluate a finished water by anything less than a "Complete" determination. In the case of raw waters or waters in process of purification the group approves a "Confirmed" test or even, in some cases a "Double Presumptive Test" if the use of such a method will result in more samples being examined and a more prompt judgement being reached as to the quality of the water and the efficiency of processes. In order to produce a consecutive picture of purification efficiencies it may be necessary to tabulate certain results on finished waters when they have given a presumptive or confirmed test. Such tabulation shall be considered as a comparison basis only and finished waters shall be carried to completion.

3. In cases where brilliant green lactose bile is used, it shall conform to the composition of Lot No. 15526 furnished by the Digestive Ferments Co. as follows:

	grams
Dried Oxgall	20
Peptone	10
Lactose	10
Brilliant Green	0.0133

For a water inoculum of 1 cc. or less or for loop inoculations the above dry material will be used in the proportion of 4 grams per 100 cc. media water and tubed in 10 cc. quantities. The reaction after sterilization shall be pH 7.1 to 7.4. The concentration of bile in the inoculated tube will then be 2 per cent and of brilliant green—1 part in 75,000. If for 10 cc. water samples, a total volume of water plus medium of 30 cc. is used, 6 grams of the dry mixture shall be used per 100 cc. media water with the same resultant density. If for 10 cc. inoculations the total volume of water and medium is 40 cc.—5.3 grams of the dry mixture is used per 100 cc. media water with the same resultant density. This concentration of bile and brilliant green is recommended because it shows a slightly higher degree of completion than the 5 per cent—1/20000 mixture and because the studies of Dunham and Levine show it to favor the maximum growth of the colon group. It is admitted to have a lower restraining power against organisms of the Welchii type, but affords sufficient protection in most water supplies studied.

4. The ordinary routine for waters in process of purification shall be the parallel planting of an equal quantity of water in an equal number of tubes of lactose broth and brilliant green lactose bile. If gas is produced in both in twenty-four hours the result may be recorded as "Partially Confirmed." If gas is produced in both in forty-eight hours the result may be recorded as "Double Presump-

tive." If gas is produced only in lactose broth the result may be recorded as "Presumptive."

5. If the technician desires, he may, having a "partially confirmed" or "double presumptive" test, transfer from the bile tube (which will contain a purer culture) to Endo or E.M.B. plate, and record the resulting growth as "Confirmed Coli" or "Confirmed Aerogenes."

If growth has occurred only in the lactose broth tube, transfer may be made to brilliant green bile tube and to Engo or E.M.B. plate. If the bile tube produces gas, the plate growth may be recorded as "Confirmed Coli" or "Confirmed Aerogenes." If the bile tube does not produce gas, the colon group is not present.

6. Samples which are to be carried to completion may be originally inoculated in parallel for purpose of process comparison. When both media ferment, subcultures shall be made from the bile tubes. If only the lactose broth tube produces gas, the subculture shall be made from it and carried as far toward completion as the reactions permit. In such cases the broth inoculation following plating shall be made both into brilliant green bile and into lactose broth and completion not be recorded if the brilliant green bile does not produce gas.

These suggestions are made in order that operators of purification plants may have methods of getting a fairly correct picture of the colon group presence or absence more promptly than is now possible. They are based upon work that has been carried on for several years in many parts of the country and it is the firm belief of all acquainted with the project that they will serve to improve laboratory conditions and result in water supply improvement. Few, if any, organisms of the colon group found by present methods will not also be found by the proposed methods and more samples can be studied.

REPORT OF THE TREASURER FOR THE CALENDAR YEAR 1926

I submit herewith my report as treasurer of the American Water Works Association for the calendar year 1926.

The funds of the association are on deposit with the United States Mortgage and Trust Company at their bank, 55 Cedar Street, New York City. This bank was selected in 1921 by vote of the Executive Committee.

RECEIPTS AND DISBURSEMENTS, JANUARY 1, THROUGH DECEMBER 31, 1926

Receipts

Balance on hand January 1, 1926	$4,301.31	
Received from Secretary	39,241.64	
Interest on deposits	84.48	
Interest on permanent investments	540.00	
Interest and profit on temporary bonds	164.44	
Sale of temporary bonds, less interest and profit	10,234.74	
Total		$54,566.61

Disbursements

Expended in payment of vouchers aggregating 379 in number, and comprising vouchers 2313 through 2692, both inclusive, except voucher 2315 which covered the check collection charges made by the bank in December, 1925	$52,874.18	
(Checks bearing the same numbers of the vouchers have been drawn, with the exception of those vouchers which cover charges made by the bank on check collections, and the amount of such vouchers is set forth below.)		
Exchange on checks as charged by the bank	15.88	
Deduction for four checks returned by the bank for various reasons	42.25	
Total		52,932.31
Balance, January 1, 1927		$1,634.30

In the above receipts there is included an item of $10,234.74 representing the purchase in March, 1926 of $10,000 of United States Treasury 4¼ per cent certificates, the amount as given including the interest up to the time of purchase. These certificates were purchased to increase the interest return on this amount, which for the time being could be taken from the current bank account. Later, as additional funds were required, the certificates were sold, the last certificates being sold in September, 1926. The net interest and profit resulting from the purchase of these certificates was $164.44.

Included in the disbursements is an item of $10,234.74, representing the purchase price of these Treasury certificates, including interest to the date of purchase. It is to be noted that the balance at the end of the year was $2667.01 less than at the beginning of the year. This was due to the cost of operating the association exceeding the receipts. During the year 1927 it is anticipated that the increased revenue from increase in dues and other sources, will prevent the expenditures exceeding the receipts.

COMPARISON OF TREASURER'S BALANCE WITH THE BANK BALANCE.

Bank cash balance at close of business December 31, 1926, as shown by December statement, U. S. Mortgage & Trust Company.. $1,993.41

Checks outstanding, December 31, 1926

Drawn in 1924:	*Drawn in 1926:*
No. 1448—$0.18	No. 2477— $1.74
No. 1512— 1.57	No. 2681—103.70
No. 1546— 3.96	No. 2684— 55.00
No. 1578— 1.74	No. 2685— 50.00
	No. 2686— 2.05
$7.45	No. 2687— 2.05
	No. 2688— 0.84
Drawn in 1925:	No. 2689— 18.36
No. 2123—$2.38	No. 2692—115.54
	$349.28

Total outstanding checks.................... 359.11

Net bank balance, which coincides with the treasurer's balance..................... $1,634.30

Receipted vouchers have been returned to the secretary. The cancelled checks and duplicate deposit slips, with the account book

of the treasurer, have been submitted to the Auditor, and checked and returned by him.

The permanent fund was not changed during the year, and at the end of the year consisted of the following bonds, which were then in a safe deposit box at the United States Safe Deposit Company, 32 Liberty Street, New York City.

4—$1000 Dominion of Canada 5%	$4,000
1—$1000 U. S. Liberty 2d, 4¼%	1,000
2—$1000 U. S. Liberty 3d, 4¼%	2,000
2—$1000 U. S. Liberty 4th, 4¼%	2,000
3—$1000 U. S. Treasury 4¼%	3,000
Par value of permanent fund	$12,000
Interest on permanent fund	540

The above bonds were checked as to amount and attached coupons by the Auditor.

There has been a change made in the permanent fund since January 1, 1927, for the purpose of increasing the interest received, which will be set forth in the account of the treasurer covering the completion of the term of his office, which will occur at the end of the coming convention.

The treasurer received no salary, and is under $10,000 bond, which has been placed by the Finance Committee.

William W. Brush,
Treasurer.

ANNUAL REPORT OF THE TREASURER OF THE ELECTROLYSIS FUND

May 31, 1927.

I submit herewith my report as Treasurer of the American Water Works Association, for the electrolysis fund, for the calendar year 1926.

The electrolysis fund is on deposit with the United States Mortgage and Trust Company at their bank located at 55 Cedar Street, New York City.

RECEIPTS AND DISBURSEMENTS, JANUARY 1, 1926, THROUGH DECEMBER 31, 1926

Receipts

Balance on hand January 1, 1926	$1,187.92	
Interest on deposits	21.68	
Total		$1,209.60

Disbursements

Payment to Albert F. Ganz, Inc. (Check No. 21)	$114.65	
Total		114.65
Balance, January 1, 1927		$1,094.95

This balance is the same as that shown by the bank notice in its December, 1926, statement.

William W. Brush,
Treasurer.

SUPERINTENDENTS' QUESTION BOX SERIES[1]

TO WHAT ACCOUNT SHOULD CONSTRUCTION EQUIPMENT BE CHARGED?

Stephen H. Taylor (New Bedford, Mass.): We have two trenchers, a steam shovel, air compressors and a steam derrick. Any minor repairs that take place through the ordinary running are usually charged to the particular job on which the machine is working. For example, we bought this machine for an extension in laying a 40-inch pipe, and repairs were charged to that job. It has been working recently in some ditching work in connection with draining some of the swampy territory around the ponds. While that work is going on it is charged to that job, that is the ordinary small repairs. On any serious repairs, these equipments would be charged to account of tools, which account is included in our mains extension account.

We have no back fillers and air compressors are charged on our tools account, because that is going from one short job to another. Our trenching machines, of course, are not used on short jobs. The repairs are usually charged to jobs on which they are working, when it is finished up or broken down.

M. C. Kinder (Youngstown, Ohio): We have a plan for handling this particular item which I feel is rather complete, in so far as we have a department called "auxiliaries." Auxiliary equipment is one branch of that department or system of accounting. In our auxiliary department expense we have such operations as machinery, like the shop, garage, or automotive equipment and a division under the care and supervision of a general, all-round mechanic who is manager. This division is called construction equipment. In that department we have our two trenchers, air compressor, back fillers, tractors, trailers, our special pipe handling truck and our truck crane.

We considered for some time where to allocate the cost of maintenance and upkeep and how to distribute it equally among our vari-

[1]Presented before the Chicago Convention, June 6–10, 1927.

ous departments, which are main construction, maintenance and service construction.

Those three branches use our machinery. We have in addition a building construction division. We do all of our own contracting. Our expense or rather the life of our machines is estimated. We try to establish a rate based on the average life of such equipment.

We have an hourly rate for all of our machines, which this auxiliary department calls construction equipment and which we charge into main construction, service construction or maintenance. We are taking our compressor out on the road and charging one dollar and fifty cents an hour to that job, which money is actually transferred on the books into our auxiliary equipment department. The one dollar and fifty cents an hour price must absolutely support that machine. This department keeps its own costs. It has a system of cost and repairs in the operation of this machinery. This money goes back to the department and is placed to the credit of that machine at the end of five years, if it is correct to estimate the life of an air compressor at five years, a trenching machine at five, and a back filler at three. We attempt at the end of those periods to have money enough in those funds to replace the equipment. In that way we have continuously kept up an assortment of equipment, our additions to equipment being out of a surplus which we accumulate.

To determine this rate is quite a problem. We have been doing it now for three years and we found we made too little charge in our estimate. On the other hand, we felt that we should get two dollars and fifty cents an hour from one of our departments for the operation of our trenching machine, and later found that that was too much. Because of the amount of available time and the low cost of that particular unit over the first two years, we were going to have in our treasury, by the end of a five year period, enough money to buy three or four more machines.

We revised our rates downward. Every quarter we check up to get the rate per hour. We feel that at the end of those machines' useful lives we will have enough money in the fund to make replacements as well as keep those machines in wonderful condition. The expense of operating them is never charged to any one job. All departments pay the same for equipment and operation. Each department superintendent has to get his order in for construction equipment in his turn so that he will have a machine when he wants it.

Mr. Taylor: To what is your first cost charged?

Mr. Kinder: We set up a capital account. It all comes out of capital. We do not include picks and shovels. We just take major equipment. Our investment runs about $1000.

W. S. Patton (Ashland, Ky.): I am very glad to have heard Mr. Kinder discuss the accounting method used on these items. Our own system in Ashland, Kentucky is not so good. It has been our practice at the close of each year to bring our equipment as nearly as possible up to perfect condition and to charge these replacements and unusual repairs into what we call an excavating account. We then apportion the amount charged into the excavating account among the different construction jobs on the machines that have been used. This method has proven fairly satisfactory, but by working out fairly accurate cost data it would have been easier to have charged rental on these different items direct to the job at the time the job was finished. The advantage of Mr. Kinder's method is that when the job is finished you know exactly how much is going to be charged to that job.

Mr. Kinder: Perhaps some of the men here would be interested to know how many men we have handling this sort of thing. The question might have been raised in your minds as to the amount of detailed accounting necessary to handle the job in this way. At Youngstown we do all of our own construction work, all of our service installation, every bit of our building and small construction jobs, even to the repaving of streets. We have only one timekeeper, an accountant, and he has no trouble at all handling this detail of cost accounting. It really comes from the source on our daily time reports, which are turned in by the head of the department for these men. There is absolutely no excessive overhead or costs in keeping this system. It is convenient and has paid well for its time and trouble.

David A. Heffernan (Milton, Mass.): I am very much interested in this subject. Of course, it is something new to me. This year we have purchased an excavator. I was quite surprised at the difficulty in finding information in regard to the cost of operating the different makes of machines. Before purchasing our machine, which

is a gasoline machine, of 60 horse power, weighing about 17 tons, and in trying to get the information from the different cities using the machine, I found there were very few gasoline machines around the city of Providence and the nearby cities. They use steam machines and not gasoline.

We started on a job just before I came to Chicago and the nature of the soil was such that it required hard work to get through. The city of Quincy is noted for its granite and old granite teams or trucks that went by the streams and marshy lands would lose a bit of granite; a block would drop off the truck and break and would be thrown into the marsh. That condition has made the ground terrible to plow through and we took out blocks of granite $\frac{3}{4}$ ton in weight.

W. S. Patton: Not with the trenching machine.

David A. Heffernan: Yes, with the trenching machine. We went through 2100 feet and took out blocks $\frac{3}{4}$ ton in weight, just nosed them right out. I saved a good deal of money by hand you might say. We do that on all the road work and I have saved $1500 on that job just by using that machine. There were granite blocks wedged in there so tight it was impossible to move them any other way than by using this machine.

W. S. Patton: Is there anyone here using a different type machine and getting less depreciation?

David A. Heffernan: Our machine cost something like $8000 and we have a setup for a five-year term on that. I would like to get the daily operation expense. We figure using that machine one hundred and fifty days in the year with the water, sewer and street departments.

Albert R. Davis (Austin, Tex.): When we run into the glacier formation where we have boulders and nigger heads too large to handle, we use an excavator and clam shell. Sometimes these boulders run as high as three or four tons. We do not attempt to roll these out with the trenching machine or to blast them out. If we cannot dig a hole around them we hire our Universal drill a few hours and the boulder or nigger head is lifted out and rolled on to the truck and hauled off somewhere to a dump.

MR. KINDER: It has been our experience in work of that kind that the chain type trenching machine is not practical. Perhaps you could get one hundred and fifty working days from your machine, but we feel in Youngstown that it is hardly safe on a piece of trenching equipment to estimate over one hundred available working days per year. We base our rate on that number. We feel if our machines work one hundred days a year for five years they will have paid well for themselves. Of course, if there is any excess that is just clear profit and we can reduce our rates accordingly.

W. S. CRAMER (Lexington, Ky.): I might say to the men of the smaller towns who want to avail themselves of the trenching machines, that almost all of you have some contractor in the vicinity that has various types of trenching machines. If you will get in touch with him and give him the work of the smaller operations in the off periods you will be surprised how cheaply you can have that work done by contract. It is worth looking into.

MR. KINDER: The problem of picks, shovels and other small tools is rather difficult. We have felt that to equip tool boxes with the ordinary amount of tools for the job, making replacements by charging it to the job itself is a pretty good plan. If the tool is lost on a job, certainly the cost of that replacement, say of a shovel, pick, lantern or whatever it is, should be charged to that particular job. Those things do not all wear out at once, they are being continually replaced so that we can charge such equipment into miscellaneous cost of doing a certain job. Out storekeeper has a job in that. A man cannot requisition a dozen new picks and shovels and get away with it in our department. If he tries such a thing there is some question and we refer his requisition back to his supervisor. That supervisor certainly has more tools laid away in the tool room somewhere which are charged to his department.

We do not let a tool out on a job without a requisition. If a man wants as many as five lanterns he can requisition them from the storeroom. If he wants two dozen it is up to his supervisor or he may provide those from other jobs. We aim at all times to avoid a surplus of tools from the division. Just as many as they need and no more. Of course, they have some from the blacksmith's shop, but we try to charge that to replacement of lost and worn-out tools, not to the job.

W. S. Patton: As I understand it, then, you start the construction of a water main on a certain street. We will say you have a supply of tools on hand to start with. Before the job is finished perhaps you may need five or six new shovels. Are new shovels charged to this particular job? In other words you are replacing the tools very gradually and the cost is absorbed by the job upon which they are used.

Our practice has been to charge these tools to our excavating account. Then we take the number of feet a trench has been dug by hand tools and apportion the cost of these tools into that account. It looks like small business, but it is nice to get it as accurate as we can.

W. S. Cramer: We charge extensions for new work directly to the new account when they are purchased. Of course, our tools for tapping and those things are made up and are never used for excavation work. They appear in the records for tools.

W. S. Patton: To what account is truck expense charged? Some trucks, of course, are used in construction work exclusively and others are used proabably in putting in service lines, setting meters, etc. What method is used in determining the proper charge for tires, repairs on your trucks and supplies.

W. S. Cramer: We have an automobile account, which includes horses, carriages and automobiles. Horses are almost a back number, but we have a few at the pumping stations and to work in the woods.

All new cars, repairs and everything are charged into the automobile account. When we are laying a main or anything like that we charge a certain amount of money to that job as automobile rental, just as we do with out cartage. On a large main pipe job, we charge the driver's time to that job. Of course, the miscellaneous running around still remains in the automobile account. We charge only the larger jobs, such as pipe laying, etc., to that account.

Mr. King (Cleveland, Ohio): We charge a good deal to capital account. We have a great number of trucks and passenger cars. We carry the operation of these machines, trucks and so forth on the books against the maintenance and operation account. The operation is separate from the maintenance, and on our large construction

jobs, a certain rate, depending on the size of the truck, is charged against that particular job as rental. On the smaller jobs in that connection we charge it to the consumer. We have smaller trucks with a rental charge per hour against that particular job, so that the rental charge we get on all the trucks will very nearly offset the maintenance and operation of these trucks. On the passenger cars, of course, we do not attempt to allocate any of the expense to the job itself, as supervision is charged as a maintenance or operation item of automobiles. We have a certain amount each year, based on our previous expense, as to what our budget must cover the following year, so we get into the job on trucking a fair charge for the use of machines.

W. S. Patton: I wonder if I understood Mr. King's explanation. I suppose you take each truck and charge all the gasoline, tires and repairs into one account. Say this is truck No. 1.

Mr. King: No, we do not charge to that particular truck. All the expense on the various trucks is charged into the truck expense account.

W. S. Patton: Mr. King has figured out about what it would cost him to rent those different trucks per hour. The driver of the truck keeps a record of the number of hours of service given to each truck job. Suppose a truck runs down to the depot about two miles distant and picks up something and runs back to the pumping station. It only took about twenty-five minutes. What would you charge that to?

Mr. King: The man in charge of the trucking division does no work with any trucks unless he gets a requisition from the department wishing to use that truck. Of course, if there is a pick-up job or a half dozen pick-up jobs, about all one can do is charge an estimated amount, including the time going to the station, picking up things from two or three different plants, and allocate that time and charge on the requisition. But that does not apply as much to the construction end as to the operation of small pick-up jobs.

W. S. Patton: I know of a plant not very far from Ashland that charges so much per mile. I believe they figured the cost of operating this truck to be ten cents a mile and each job is charged ten cents a

mile. If the cost runs more than ten cents per mile, the truck driver is called in to explain. If, at the end of the year, they find the truck has been operated for less than ten cents per mile there is some reward that goes to the truck driver, a box or a carton of cigarettes or something else. They use these operating costs or postings to stimulate the truck drivers toward extra effort in lowering costs.

Mr. King: All of our machines are classified. There has been a division started to take care of and find the actual cost for operation and maintenance of each machine. Numbers are put on each truck and on the passenger cars, instead of putting on speedometers, and a daily record of the gas and oil and everything that goes into that particular truck or passenger car is kept, so that within probably a year's time we shall have valuable data as to what the operation and maintenance of those cars are.

Stephen H. Taylor: I think we are splitting hairs when we try to make the division other than between capital account and operation. The little question of distributing these items should not be taken seriously. I do not believe anyone here does take it seriously. For instance, we had a question come up not long ago on a tapping crew out on a tap. The question arose as to whether to make a distinction when the water had to be turned off and on and an emergency turn-on, one that is not taken care of in the usual way. We decided that those things could not be divided. It is trying to split hairs when we try to divide them. It is purely a give and take proposition. Suppose we have a break or a hydrant knocked off. We can locate a tapping crew while our extension or maintenance crew is probably some distance away and we do not want to disturb them. We make no record whatever for taking that tapping crew on account of the broken hydrant.

TAXATION OF WATER WORKS PROPERTIES OUTSIDE OF CITY LIMITS

Stephen H. Taylor (New Bedford, Mass.): The Massachusetts law is very strict in this regard. The water taken for water supply in other towns is not taxed, but in lieu of taxation they pay at the regular tax rate on a valuation which is arrived at by taking the average of the valuation of that property for the three years preceding the time when the city took it. That value was fixed for all time and the rate fluctuates with the tax rate in the town.

For instance, in our pumping station we do not pay a special tax. We pay in lieu of that a tax on the property on which the station is located. In other words, the town gets just about the same revenue from the land which the city takes as it did before we took it for water works property. There is no increase on account of improvements or decrease on account of cutting off work or anything like that.

Mr. Bright (New York, N. Y.): I simply wanted to say we have to pay taxes on our property. The tax is not on the previous rate of the land, but it makes it convenient for equipment rates on the property. It is a much higher rate than the previous rate on any particular parts of the land.

W. S. Patton: Mr. Taylor, how does the assessment compare with the investment cost of the pumping station you speak of?

S. H. Taylor: In the tax assessment?

W. S. Patton: Yes.

Mr. Taylor: I should say we bought most of that property on a very low rate because it was not known at the time that it was to be taken for water works purposes. It was supposed to have been bought for pleasure resorts.

It seems to me the valuation placed by the town in most cases is rather less, as few cities and towns expect to tax property at full

value until they find it is being taxed that way. There are one or two exceptional cases that are taxed for a higher rate than when purchased, but in the long run I should say the valuations are below the price paid by the city.

W. S. Cramer (Lexington, Ky.): Mr. Taylor says they are taxed only on the land. Is there any person here whose city is taxed for the water mains or taxed for the pumping plant, pipe line, or other service, lying in the county outside of the city?

W. S. Patton: Mr. Cramer, are your water mains outside of the city taxed as well as your pumping station properties?

W. S. Cramer: In our case we are charged for water mains and pumping station besides the tax on the land itself.

C. F. Drake (Pittsburgh, Pa.): We are not taxed for our water mains, but we are taxed for the reservoir and properties. We have a concrete reservoir outside of the city.

ONE OR TWO MAINS ON WIDE STREETS

E. F. Dugger (Newport News, Va.): We have adopted the double main procedure in practically all of our main business and residential sections. We have there a possible advantage over some of the other communities. Our township was laid out by one individual who owned the whole community. Our streets are of uniform size, our blocks are of uniform size. Of course, the avenues and all streets are the same width. We have a parking strip between the curb and sidewalk. About two or three years ago quite an extensive paving program was instituted in our city. Practically all the streets were paved at that time. We adopted the method of installing a small main on the opposite side of our street where we had renewed the service for this paving work.

We have not been governed so much by width. We have found our saving has amounted to quite an item in this work. We have a very well graded system and we tie our 2-inch main in, for instance, on a 550-foot main block where we have a large size main on the street. Our main will be on the south side of the street and on the north side a two inch main will be run and tied to each end of the large main. We can then cut off either side of this section and still give water for the whole business section. In that way we have avoided all of the long services and we have cut down the cost of our renewals. We can put in also a swing joint for our service connection.

I do not believe this is feasible in all cities, but, since we have no paving to break up, we have an economical procedure.

W. S. Patton: Are they cross connected?

E. F. Dugger: They are at the end of each block, every 550 feet I should say, and are tied on a well graded system.

W. S. Cramer: Mr. Dugger, were your original mains so located that in paving the street you did not have to re-lay them?

E. F. Dugger: We have an established grade. In Virginia there is not much frost. If we are down two feet, we are absolutely

safe. We never go on a street until the city says so. At this time it was under private ownership and we never laid a main until we had instructions from the city engineer. Our grades have never been broken and with probably two exceptions we have never had to re-lay a main on account of that.

W. S. Cramer: A great many people have adopted the practice of putting in a 4-inch line. We have gotten into trouble doing that, so we have adopted the use of the 2-inch cast iron main for the outside and we are getting very good results from it. While we are not getting the circulation, the use of the water on the line helps the condition over the one we had in the 4-inch.

Mr. Kinder: May I ask the gentleman what the widths of the streets are, that is, the minimum width?

W. S. Cramer: A uniform width of 60 feet between curbs. That is what we have on all our streets, and 80 feet between property lines.

Mr. Kinder: How much paving do you have?

W. S. Cramer: These streets to which I refer are paved the full width. If they are not we do not bother with double service.

W. S. Patton: If it is 80 feet to the property line, of course, you have room in there for sidewalks on each side? In the natural paving of your streets, probably where you are using those dual mains, the street is not paved more than 30 to 35 feet perhaps. Is not that about right?

Mr. Dugger: I think I did use the word parking strip. Our sidewalks do not come all the way. We have a space for trees, not the parking strip itself. Our streets are paved solid from curb to curb.

W. S. Patton: What is the general width of the paving?

E. F. Dugger: Fifteen feet from the curbing line.

Mr. Kinder: At Youngstown we do not make any attempt to use double mains. Our streets average 50 feet. Where we do run into a

wide street, we believe there is a balance of economy which may be effected by the dual system. We charge uniformly for our service, installing them all ourselves. We charge each side or each lot a uniform price regardless of the size of street. We do not double main unless by so doing we can salvage enough or save enough on our service to pay that cost.

In our town the consumer pays for his service from the main. If a 50-foot street has a certain price, on which we have found we can come out even or where we can justify the investment in the second main, in lieu of excessive cost of service, we do it.

Another thing entering into that which is quite a factor is the grade of development in the particular section. We do not attempt to double main unless we feel certain the street is going to build up quickly and we will get back our investment in the second main very quickly from the excess cost we have charged to the consumer for his service.

Mr. Patton: I would like to ask Mr. Kinder what size he generally uses for the secondary main?

Mr. Kinder: We have never considered anything smaller than 4 inches.

Mr. Patton: Mr. Cramer stated that 4 inches had been giving him trouble. I would like to ask Mr. Cramer what trouble he has experienced from using the 4-inch main.

Mr. Cramer: Lack of circulation. I cannot explain it except to say it is there.

Mr. Patton: The water has a strange taste.

Mr. Cramer: Yes.

Mr. Patton: About how far apart are the cross connections?

Mr. Cramer: The distance of the average city block.

Frank A. Lyon (Oneonta, N. Y.): The gentleman over here has hit upon a question that is practically the same condition that we

have in our work. There is an 18-inch main running from our reservoir to our filter plant. There is also a 10-inch main and we find by the tests made from the operating end of the plant that we get practically no water unless we exceed 2,000,000 gallons. They are both at the same elevation in the reservoir and we cannot determine why our 10-inch main does not feed the same as our 18-inch.

Mr. Cramer: We have two or three sections in our city streets feeding right around our 4-inch mains and we have a great deal of trouble with red water. Of course, our city is troubled with red water a great deal and that is one of our problems. We have practically overcome it with the 4-inch mains, but we have never determined all of these matters to our entire satisfaction.

James Sheahan (Memphis, Tenn.): We have some 4-inch lines and we are taking care of the future growth of the city. We have some streets in Memphis as wide as 60 feet. In some sections we are putting in a main on each side of the street, but where we have a street 50 or 60 feet wide we tap across with one branch in the middle of the block, or we make a practice of going every 100 feet, according to the amount of water that is to be used on the opposite side. We run on the sidewalk and put a stop in there and extend our lines so that we get circulation enough to keep the water moving all the time.

When there is circulation in the 4-inch line, the 8-inch line can take care of all the supply. If you will carry your line across the street and make your connection on the side according to the size of the houses or stores you serve, you will get rid of all that trouble.

We are going into all our subdivisions and figuring out the needs according to their size, putting in a 6-inch line for a distance of 1000 or 1500 feet. We put a header in the other way, large enough to supply the street beyond that. We have a project on hand for next year. They have annexed a part of the city, about 30,000 people at the edge of the town and we have that part all laid out. Our header mains are big enough to take care of anything in there, but we will not use less than a 6-inch main. On our wide streets we will place one large main and use these little connections across to the other side and not have over 4-inch on the opposite side. Then we will have circulation all the time. We do not put the connections on the opposite side, unless there is a house close to them, but we keep our mains alive.

If you build a house on the opposite side of the street and if the street is wide we will put a connection over there when you need it, but not before. We will not put anything in to be left as a dead main, because the water gets bad when it does not circulate. When they do not use it any more we cut it off. When a tenant moves out of a rented house we cut off the supply.

Mr. Patton: What sort of pipe do you use?

Mr. Sheahan: Lead connection. Our pressure in some places, where there are so many houses, makes the water a little muddy and we are going to galvanize soon. Our city at the present time has one of the lowest rates in the South. We are in the number two rating and we have gotten it on account of the way we are laying out the lines. We reduced two years ago from a fourth rate to number two. In the beginning just a few 4-inch lines were laid, but we are taking them all out.

Mr. Lyon: I would like to ask the gentleman if he is troubled with red water?

Mr. Sheahan: No, we have well water. If you will aerate red water you will get rid of it all and you will not have any trouble doing it. We have the same condition in Memphis. There is CO_2 gas in the water. It turns red in the mains and, when you boil it, it comes up to the surface. It will always show up under pressure. Cold water does not give so much trouble under pressure and will not be noticed to such an extent, but as it is heated it rises. We have practically eliminated red water. We use from $\frac{1}{2}$ to $\frac{3}{4}$ grain of soda ash per million gallons of water and that increases our CO_2 up to 7.5, or about 7.8. What you want to do is get the CO_2 out of it.

Mr. Lyon: That is our difficulty. The alkalinity is so low in the water we have to increase it in order to overcome the red water.

Mr. Sheahan: I will give you our experience in Memphis with red water. Anyone who uses artesian water knows red water is connected with it. We put in our pumping station. We had been using three different kinds of pumping systems. The last time we put one in we had some exhaustive tests made to determine what kind of pumping

system we should use, and after testing the matter out we found that the air lift took out about 70 per cent of the gas that caused the red water. We have a filtration and aeration system which take it all out.

We have some curious streets. There are so many different widths and conditions it is hard to tell exactly what size street we do use. We take not only a wide street, but a paved street, asphalt, concrete, of any kind and do the same thing. We put our mains in the grass plots, if we have them, and if not we put them on the side streets. We have many conditions where the old fashioned equipment is used. At one time we put them down in the middle of the street, then the street cars came along and camped on top of them and we were everlastingly repairing the mains. Now we do not put anything in the middle of the street. If we have a grass plot, we go on the side, then we lay these lead pipes for one side of the street and whenever there is a house built there we give the connection. We do not dig up the street at all.

Mr. Cramer: The reason we use 4-inch is because we prided ourselves on the fact that we had nothing but cast iron and lead in the entire system. We did not want to use any other material for piping those lines, until seven or eight years ago when they brought out the smaller sizes of cast iron pipe, we saw the advantage. Since then we have used those smaller sizes of cast iron pipe. Some of the smaller jobs we are taking care of with $1\frac{1}{4}$ inch cast iron pipe. We had to use that kind. There was nothing else available except lead. As this was costly and rather hard to handle we just used the 4-inch cast iron lines.

LAYING SERVICE PIPES IN ADVANCE OF PAVING

Mr. Kinder: I feel there are certain conditions surrounding this practice which should temper one's judgment. It depends a great deal upon the rate of development of the section being paved. It is absolutely uneconomical, although we do it in Youngstown. Youngstown is a rapidly growing city. As soon as a paved street is down, one might say that fully a 100 per cent built up condition is reached within three or four years. Therefore, we feel that it is absolutely the thing to do, rather than make the duplicate investment in additional mains or dig up paved streets. In a community which is not well paved, conditions would be different. If you were paving a main highway out through a district which is probably not to be built up, but is merely to be used for through traffic, perhaps the service lines in advance of paving is not justified.

Mr. Cramer: We thought the same thing, but experience has taught us otherwise. I can now think of two instances, one particularly of a large hotel built in what was once a residential section and is being tied into the business district. Fifteen years ago we put five taps on that piece of property. This particular property was a small one and had developed into a center for automobile accessories and things of that sort, all owned by one man, and one supply was taking care of all the stores. This hotel was built and they took a 4-inch connection. We have on that property five connections which in the natural order of things would have been used, but the original plan has been abandoned and the other four taps have not been picked up.

We have several instances of just that kind and we have come to the conclusion that it is not worth while. You do not know what the development or what the size of the connections will be. When it comes to the residential sections it is almost useless, because one lot line changes the whole situation. We have added as many as three taps on one lot and no taps on the corresponding lots. You can never get them right. They are a continual source of expense and a bugaboo of tearing up the pavement even on the five-year limitation. There is simply nothing to it in this day of modern repairs.

Fred B. Nelson (Highbridge, N. Y.): In New York City we have had extreme trouble in locating leaks from old abandoned service pipes. We thought we would be very much averse to putting anything in the ground that we did not know definitely would be used immediately. As some of you probably know, an abandoned service pipe, especially in a congested location like New York City, is very apt to cause serious trouble in locating when it leaks. Due to the fact that there is no vibration set up, since it is too far from the main to set up any, we have frequently in New York City had to put down sounding holes in many places in the street off the line in order to locate the leaking end of those old abandoned service pipes. They were not put in with the idea of reaching any future development. They were simply abandoned where they became too small to serve the purpose.

I think our trouble in locating leaks that develop in these old mains, which were put in and never served the purpose for which they were intended, when the development comes along, justifies doing away with that practice.

Mr. King: Our general practice is and has been for a long time to put in our service connection in advance of paving, because as the gentleman from Youngstown said, development is very rapid in new streets that are laid out. In case we find the connections are not large enough, I do not know whether it is the practice to plug the old ones at the main or not, but we do that where other connections are put in or larger ones are used, and charge the expense against the property.

Stephen H. Taylor: One point that has not been brought out and which is probably practiced by all of you, is that in advance of street paving everybody should be notified by the city authorities that the street is to be paved and cannot be broken up again within five years. Unless the owner shows an interest, at least enough to make his application and tell us where he wants his service and what size he wants, there is no use bothering with it. We have had the experience of putting in the service and it would not be the right size or in the right place. In many cases it is never used, so there is not much difficulty after all in replacing the pavement if you go at it properly.

On the short side of the street we cut only one opening, tunneling

the rest of the way. On the long side we make two openings and tunnel the rest of the way. We pass on to the owner of the property the cost of surfacing that street.

We have found that it is not really worth while to put in pipes in advance of paving.

David A. Heffernan: They are putting in force in Milton today something which I do not approve, in regard to sewers, gas and water.

On a new construction a permit is granted by the engineering department of the different utilities and the location is granted for the sewer, we will say. The sewer is put in first and then the water is put in on a table or a bench on one side of the sewer. The gas is put in on the opposite side. There is only one opening. I am strictly opposed to this layout, but I did not have strength enough to stop it from going through.

Several years ago this very same question came up in The Association. It was thoroughly discussed and the consensus of opinion was that it was poor policy, but we now have in the town a new engineering department that started last year so this layout has been approved. In some conditions it can be worked out all right. I believe it is all right where there is a ledge when you sewer the street to save the consumer the cost of putting in the several trenches and the cost of excavating.

The gas pipe does not go very deep, about 18 inches or 2 feet, but the sewer goes down the depth of 5 or 6 feet. In making the excavation in loose or soft material it is almost impossible to put the water trench in and you are bound to get settling from that sewer trench. The idea is to reduce the cost of paving and not to spoil the street in taking up the different connections.

W. A. Hutchins (Freeport, Ill.): We followed the practice that Mr. Cramer has outlined in our town. We do not construct this service in advance of the paving for the reasons stated before. The development has grown so fast following the paving that within two years we have probably the entire street ripped up. I was wondering what they did in Mr. Cramer's town, for instance, with the sewers. Are the house connections omitted in advance of paving. There is no argument for putting in the sewer studs and none for the gas service. For every lot that means three separate excavations. Our sewer studs as a rule are put in by contract and that means a separate

trench for the sewers and a separate rate of contracts for the water service.

This year, and in fact a considerable part of last year, the water department constructed the sewers in connection with our work. We constructed them in the same trench as a rule by putting the water service on the side and we have been getting along pretty well.

As far as the service not being properly located when the street is developed, we think we have overcome that. In fact we have never had any trouble in that respect. There have been a few cases where a building much larger than was anticipated is being constructed on several lots where you probably did bury three or four or five service lines that were never used. But that was the exception rather than the rule. In the residence properties we believe we waste less than one per cent of the services we put in.

We have an ordinance that provides for a certain development and we place these studs to fit into that development. People always take advantage of the most intensive development that it is possible to make along the street after it is paved. We would never think of leaving out service in advance of paving.

Mr. Cramer: I was speaking of the older residential districts which are developing into business districts. In the newer districts with your parking space on the narrow streets, we are putting the pipe in the parkway. On the wider streets we are using a wider line. We do not pay any attention to the tapping. When we have a main in the parkway we use a pipe pusher and do not disturb the street at all. We have quite a system of national and state highways entering Lexington. Our mains there are laid on the side of the highways clear of the improvements. We use the pusher on the off side in all cases and we do not disturb the street or highway in any of those sections.

Mr. Paster: Do you use iron, brass or lead pipe with the pipe pusher?

Mr. Cramer: We use the lead pipe.

FLUSHING MAINS

Chairman Patton: On calling for a show of hands, I find that we are about evenly divided on whether to flush during the day or during the night.

Mr. Lyon: We do not flush during the day except on the main street.

Mr. Nelson: In most cases we do our flushing in the daytime.

Chairman Patton: Do you isolate the mains being flushed? I will ask you to hold up your hands if you are in the habit of isolating the mains when they are being flushed. That is to flush one main with the side lines cut off so that you can flush straight through. Those who do this please hold up your hands.

(Seven hands.)

Chairman Patton: Evidently the rest of you do not.

Mr. Cramer: I would imagine most of the flushing is done on dead ends. The only time that we use the shutoff system is in the spring and fall when we have a general draining of the smaller mains. Most of our flushing in the summer is confined to the dead ends. Lexington is laid out with the turnpikes running into the city much like the spokes of a wheel and, of course, we have a lot of dead ends. It is almost impossible to tie them in and those are the ones that get the most attention. Occasionally we have a bad condition and then it is necessary to shut off to clean a small main where the circulation is not good.

Chairman Patton: In Ashland we find it an advantage to flush the mains four times a year. We flush the entire town. We do not take the time or the trouble to isolate any mains. We start at the upper end of the town in the business section. We isolate one section so as not to get the water muddy or disturb any other mains. We

will go down through the business section and get that flushed at night. The next night we take another section and so on until they are all flushed. Water is always improved after the mains have been flushed.

I was surprised to know that it is the practice of so many plants to isolate the mains being flushed. That is considerable of an effort, isn't it, Mr. Taylor?

Mr. Taylor: We generally start at the end of our system nearest the reservoir. Of course, those are large mains. We shut off certain sections of one of the mains and feed it down through the other, thoroughly flushing that main in that section and take the next section and so on down through the whole city, isolating each section by itself. In most cases where it is not a straight run, but a round-about run in sections, we let the water come through, first, one way and back the other way through the same section. For instance, if we shut off four or five gates to one section, we will flush it through one end first and then close that end and flush it through another end. It takes time and some effort, but we go through the whole city at least twice a year, flushing every inch of main in the city and filling it with fresh water. Dead ends are flushed more frequently, as the occasion requires. We find it well worth while to take the extra pains to do it systematically by starting at the source and working down with clean water all the way.

Mr. Cramer: It strikes me in a ten inch main or longer, if you do not shut off your pipes you are just going to stir the water. You do not get a flushing effect unless you have your main isolated.

Chairman Patton: How many hydrants do you open at a time?

Mr. Taylor: It depends on the size of the main. On our 4- and 8-inch lines we open everything on the line. On the 6-inch one or two hydrants will do. It depends on how many hydrants are available at the low point. In some cases we flush with waste gates into the sewers. We gauge the amount of flow through the pipe by the size of the pipe.

Mr. Hershler: We isolate the mains and keep the hydrants open. We have five mains. We keep four lines open all the time to create

enough velocity to flush the mains. You do not get enough velocity to clean your mains unless you have the required number of openings to flush. We start at the flushing plant and we go right through, nightly. We flush every night and the hydrants are never shut. We have an automobile to take care of the man on the job, and that man does not shut off until another man comes to relieve him. In that way we can keep four hydrants open constantly all night. We create velocity enough so that we know we have a good, clear main.

Chairman Patton: Mr. Dugger will you explain your method.

Mr. Dugger: We isolate two mains and go on down through the system. We are in a tidewater section and there are low points. We have a drain valve at the lower ends and we use that constantly. We have an 8-inch drain. If you keep open with all the plugs through you will have no difficulty.

We have four different municipalities and we have to use practically the same methods throughout. It is clearly a matter of isolation.

Mr. Lyon: May I ask if you ever take into consideration whether to flush the high or low points? In our city the ground is quite rolling. The high district or the low district first makes little difference in the flushing.

Mr. Hershler: We always start with the pumping station. We have an upper and a lower system.

Mr. Lyon: We had a lot of trouble with our flushing at first and we followed the pipe line which carried the heavy load and flushed that first and left the dead ends to the last. We have gotten better results in that way.

HYDRANT VALVE CONNECTIONS—FLANGED OR LEAD JOINTS

W. S. Patton: In these days of automobiles when our hydrants are being struck by them everyone is having trouble. Which type of joint have you found causes least trouble, the flange or lead joint between the auxiliary valves.

Mr. Cramer: You mean by that the lateral valve, do you not?

Chairman Patton: The auxiliary valve, yes.

Mr. Cramer: Unfortunately, most of our plants were built before the automobile came and the fire hydrants we are now putting in are located in the parkways where we do not have that trouble. This question does not apply to the newer connections so much. But I am still setting them with lead joints. If I had the system to build over I would prefer the flange joint, but we have to take it as we have it.

Mr. Hershler: I do not see the difference, when they break the hydrant they break the flange too. When the automobile goes over the curb it hits the hydrant or breaks it off at the top of the ground, then you have to take it up and put in a new valve. I have never known it to fail. And so far as locking them is concerned, it makes little difference, for when the automobile goes over it goes on to the boulevard and the hydrant goes too. We have them broken into on the boulevards sometimes ten feet from the curb.

T. F. Halpin (Newark, N. J.): The drivers are getting more experience. It used to be nothing to find eleven or twelve hydrants knocked over in one night and now we sometimes go a whole year without one being knocked over. This year I think we had two. It all depends upon the type of hydrants. We use a cage type hydrant and the flange is down on the bottom. If the hydrant is struck the flange is not broken. We use a cam point for our joints when we use the lead pipe. It gives very good satisfaction. That type of hydrant is popular with us. We have been using it ever

since I have been connected with the city. I have changed in some other things, but I believe in sticking to a hydrant that gives satisfaction. Those hydrants were installed thirty-seven or thirty-eight years ago and they are still on the job.

Mr. Cramer: You know what kind of hydrant you are going to repair. That makes quite a difference. If you use the same type you are not bothered with losing parts and having trouble with the fittings.

Mr. Taylor: I do not think it makes much difference whether the joint is a flange or a bell and spigot. The break occurs at the pavement line or at the bottom flange. I think it is more important that the valve be located as near the main as possible and as far away from the hydrant as is practical. We have several cases in the none-compression type of hydrants. You get a geyser when it is broken off and the men are unable to get at the independent valve. The further away you can get that from the hydrant, the more it will improve your condition.

There is a straight type of hydrant where the hydrant bearer cannot be knocked off. You do not have to shut down the line at all. It has a bronze nut on the sleeve where the hydrant wrench goes on. To take the plate off for replacement it is not necessary to shut down. Of course when you get the geyser right up through it that would be difficult.

Mr. Cramer: I understand the hydrant stays right in place.

Mr. Taylor: I think there is an advantage in the gate type of hydrant.

Chairman Patton: I think Mr. Taylor's idea is a very valuable one. What we need in the water works field is a change of practice. Instead of putting those auxiliary valves right at the hydrant, they should be placed as close to the main as possible. The hydrants are placed very close to the main; often there is a very short distance between the hydrant and the main.

I have been wondering for the past year if it would not be advisable to have a standard design, or valve box case. Say a hexagonal box, something altogether different from any ordinary valve box, to lock the valve to the hydrant right at the main. The chief objections to

putting these valves next to main is that someone might make a mistake and shut off the water main by that method. I have never had that happen in my experience, but it could happen. If it were customary to put the hydrant valve close to the main it would be hard to determine exactly which was shutting off the hydrants and which was shutting off the main, especially when you had a six inch main. If we could have a standard valve box made of unusual construction, so that there would be no possibility of getting an ordinary valve box lid on it then there would be no danger of shutting off the main by mistake when you intended to shut off a hydrant.

F. B. McDowell (Charleston, S. C.): As far as that goes, I think it is advisable to have the hydrant braced as near the main as possible. There is a possibility of confusion as to whether it is on the main or not. I do not know whether we should adopt a different type valve box to eliminate that possibility or not. It seems to me the superintendent could specify the standard valve box, with a different type lid, placed at every hydrant. You could have H. V. on the top of the lid. If that lid gets broken, there is a possibility of the wrong lid being placed on there, and if you had H. V. on the top of the lid of the hydrant valve there might be some advantage.

If you would adhere to the round top for the valve box you would find it a pretty good practice. I would rather have it than any other I know of, even the rectangular or hexagonal type.

Mr. Cramer: It has not occurred to me in the business district where the valves are located on property lines and the hydrants are from 10 to 12 and even 20 feet from the property line. We have never had this question of confusion. I never thought of it.

Mr. Kinder: Are we not getting away from the thought of the hydrants on the corner? Are we not moving them around the corner a little further now? In the days of the horsedrawn fire fighting equipment there was an argument for putting the hydrant on the corner, because it was available from two directions. In this day of the automobile I think we have all found it mighty convenient to have it 30 or 40 feet around the corner. I see no chance of making gate valves differently, because it is common practice to put all gate valves on property lines. Hydrant valves that far away are in a class by themselves and we have a chance to adhere to standards in our valve boxes.

CHAINS ON HYDRANT CAPS

CHAIRMAN PATTON: Do you consider chains on hydrant caps necessary? One member has found it to be more economical and desirable to use a chain between the caps than a chain from an eye-bolt in the dome of the hydrant.

First, let's take the question, "Do you consider chains on hydrant caps necessary?" Let's discuss it from the fire hydrant angle. The fire departments are opposed to them. The caps bind when you try to take them off. That delays the firemen. What is the consensus of opinion here? How many of you think that fire hydrant chains are advisable?

(Fourteen hands.)

CHAIRMAN PATTON: How many of you do not consider them really essential?

(Two hands.)

CHAIRMAN PATTON: Then do you prefer to use the chain between the caps and chain from the eye-bolt and the dome of the hydrant? Let's see how many.

(Eight hands.)

CHAIRMAN PATTON: How many prefer to use the chain between the caps? I suppose we may assume that the rest of you do prefer that.

GATE VALVES AND VALVE BOXES

S. B. Morris (Pasadena, Cal.): In Pasadena we operate every valve in the system up and down once a year. We have one or two men go around throughout the year to maintain the gate valves and repack such of those as show any leakage in the packing box or any other repairs which may be necessary. The majority of the work perhaps is taken up in replacing and repairing valve boxes, rather than in attention to the valves themselves, because we have not as much difference in our valves as in the valve box.

We find also many of the new valves, before installation, need more packing. It is our practice to open up the packing boxes and repack those that need it before installation.

C. M. Crowley (St. Paul. Minn.): The old practice was to make an examination every two or three years. I think it continues and probably with greater efficiency, for they examine some of the larger valves every year, some others every second year, and on the smaller mains and districts they are gone over each year or about every third year. We would probably give it a closer inspection, if our revenues would justify. We are carrying out a large construction program and our revenues are charged with the sinking fund and equipment that we will not use for twenty or twenty-five years probably, until our population is doubled, so we have to adapt ourselves to the revenue in hand.

Robert B. Morse (Hyattsville, Md.): We make regular inspection of our valves, operating them twice a year, fall and spring. We do just as the speaker from Pasadena does, operating them fully up and down, and we also back them off several times in order to work out any small material that may be in them. We find that works satisfactorily and in that way we are sure that the valve is tight.

We have much more trouble with the covering up and damaging of valve boxes, of course, than we do with the valves. In the Washington Suburban Sanitary District there are a great many small towns and unincorporated villages which lay down gravel or

cinder streets without any reference to the grade at which the top of the valve box happens to be and without any notification to our office. Therefore, we have to be on the job a good deal of the time doing observation work for ourselves and making such changes in the valve boxes as may be necessary.

W. S. Patton: Is there any further discussion? This brings up an interesting question. Do you use valve boxes or do you use valve vaults with manholes for your valves, and what size valves do you usually provide with manholes?

Mr. Morse: We use the valve boxes on valves of 12 inches and under. On 16 inches and up we use the manhole.

Mr. Morris: We use valve boxes on all ungeared valves and the manhole over all valves which have gears regardless of what that size is, usually 16 inches and up.

Chairman Patton: Is there any further discussion?

G. A. Corine (Superior, Wis.): We have conducted our own pitometer surveys ever since 1917 yearly. In making this survey we operate every valve. We have a practice of building vaults over all the valves that are 12 inches in size or larger, but lately wherever there is a possibility of paving the street in the near future we are putting in the vaults on all valves, no matter what the size.

F. W. Lane (St. Petersburg, Fla.): I think that we are probably stimulated and a great many others are to a much closer examination of valves by the Board of Underwriters. They have been in the service of our city every year or two, and we try to keep up with them. They go out and make their own tests; they do not like to be caught napping. It is quite a stimulus to keeping things in good shape.

SERVICE PIPES

Robert B. Morse (Hyattsville, Md.): We are just starting to use the copper pipe on surveys of $3\frac{1}{4}$ inches; we have been using $1\frac{1}{4}$ cast iron pipe before this time.

F. W. Lane (St. Petersburg, Fla.): We have just started using copper. We have been using galvanized material, and we are trying out the $1\frac{3}{4}$ inch. But we have not gone far enough to know much about it yet.

Chairman Patton: In using the copper and brass pipe no lead connection is required. The pipe is attached direct to the corporation cock. Do you use a corporation cock with that?

Mr. Lane: Yes. We use a pipe and flange off to fit. They are made for that purpose, as on gas pipes.

Mr. Morris: We use copper pipe for sewer flush connection where they go through the manhole. We had trouble with the corrosion of the pipes that go through the manhole until we adopted the full pipe.

Since we have started to use the copper pipe we have been omitting the lead, connecting the copper pipe directly to the corporation cock through a 45 degree fitting.

Mr. Lane: We find it cheaper to do the same thing. Our help down there is all negroes and sometimes they cause a lot of trouble.

Mr. Morris: There is one interesting thing we have in our old lines at Pasadena. We have a number of services, installed forty years ago from 1- to 2-inch wrought iron pipe, directly tapered into the cast-iron mains without any gooseneck. We have had no difficulty with those and they are forty years old. We have never had a cracked pipe or any broken pipe. But we do not follow that system now.

R. C. Beam (Middletown, Ohio): It will probably be of interest to know that developments are being made at the present time for furnishing vitreous enameled pipe, pipe enameled on the inside as well as on the outside of small, as well as the larger, diameters, which will be used for service pipe. That will prevent corrosion from taking place on the outside and will increase the life of your pipe over a long period.

Chairman Patton: I would like to ask in regard to this vitreous pipe, do you mean cast-iron pipe with some kind of enamel on the inside and outside?

Mr. Beam: It would be a plated pipe.

Chairman Patton: Do you mean it would be a steel pipe that will have a vitreous external and internal finish?

Mr. Beam: Yes.

Mr. Lane: What makes the joints in that?

Mr. Beam: The services I have seen have a slight coating of enamel with threads. I understand that the enameling companies have tackled the problem of making a plastic enamel. How far they are getting with it I do not know. They have run into some difficulty, but there seems to be a coating on the threads when the proper connections are made.

Mr. Lane: Could we re-thread those in a certain length?

Mr. Beam: I do not know how they are going to handle that part. I just offered this as a recent development in the pipe field. The pipe is being made in a variety of lengths, enameled both on the inside and outside, and is being used in various phases of the pipe industry.

Chairman Patton: It would seem to me that the chief weakness of a pipe of that kind would be at the threads. Where the threads are exposed to corrosion, the pipe tends to disintegrate, the same as any other steel or iron pipe.

Mr. Morse: I think the pipe would be no stronger than the weakest point in the chain.

Mr. Corine: Getting back to the question of copper pipe line, I am going to ask what is the general practice in case the service is torn out. If you have been using lead pipe, you will be interested in knowing that we have serious freezing, and when we get down on it we just pound it together again. We freeze our pipe and make our repairs. When copper pipe does not hold, we must dig down in the main and shut the water off or make a shut-off at the main.

Chairman Patton: Mr. Corine has brought up an interesting question. With iron pipe it is feasible to freeze it, if you have thick walls, and you shut off the water in that way, but with this thin wall copper pipe if you freeze it it is liable to bulge up and weaken the walls. Has anyone had any experience in shutting off water in that way, with copper pipe?

Mr. Corine: I do not think you could pound it together to stop the flow of water with the pressure on it, so you could not freeze it in the first place.

J. P. Hanley (Illinois Central System, Chicago, Ill.): I am a member of the American Railway Engineering Association and I am somewhat interested in the developments of small pipe for service lines. If there are any gentlemen present who have had experience with copper and brass, I would like them to state which in their opinion is the best. As I understand it the copper has a light wall thickness while the brass has a heavier wall thickness. In the case mentioned by Mr. Corine, would the use of brass pipe permit you to freeze that, instead of using the thin wall copper pipe?

Mr. Crowley: As far as St. Paul is concerned I cannot speak from any personal knowledge, but it seems to me I have heard the discussion from some of our foremen and assistant superintendents and others, that the brass pipe is quite brittle, due to the quality of the pipe, and they had some difficulty with the threads.

Mr. Hanley: Do you use brass pipe in St. Paul?

Mr. Crowley: We have experimented to some extent with it and have come down to the practice of iron or brass for anything of 2

inches or over. Where there is so much at stake, we find we are much better off. Our maintenance charge has increased as system gets older.

Mr. Hanley: Have you had any experience in the relative merits of copper in pipes? I saw an exhibit here which stated that there was 85 per cent copper which would do away with that brittleness. I was wondering if that would do away with the brittleness which you mentioned.

Mr. Crowley: I think that was the idea, that they were waiting for some such product as that. With 2 inches or up, I do not know whether we would be inclined to commit ourselves to that or not just yet, but we feel sanguine.

Mr. Hanley: What I was trying to get an expression on was, say, a pipe under 2 inches in size, as to the relative merits of brass. I understand that copper is more ductile and can be bent like lead, although it has the disadvantage of having a light wall thickness. I was wondering whether any gentlemen had any experience as to the general all around merits of copper or brass.

Mr. Crowley: I am afraid the subject is a little bit too new for certainty.

Mr. Hanley: In municipal practice it has appeared that lead has been the principal service heretofore and that they are now going over to copper in some cases, and possibly brass, so I was wondering if the experience had been long enough to give you an idea of current practices as compared with the copper.

Mr. Crowley: We have been using copper for about two years, but that is hardly a sufficient length of time to be definite.

William Luscombe (Gary, Ind.): I was trying to collect some information about the merits and demerits of the brass and copper pipe. We use extra strong lead entirely at Gary. I spoke of it to a couple of superintendents who had used brass, and they stated they had had considerable trouble with the brass pipe breaking where it was threaded. It was brittle and gave considerable trouble in that way. I spoke to other parties who had used copper and they said

that it was preferable to brass. By learning how to use it and using the special couplings such as were shown in the exhibit room, they got away entirely from that. They seemed to recommend it very much in preference to the use of lead pipe or brass. One superintendent said it was about one-third cheaper than lead. He had used it a few years with very good success.

MR. CROWLEY: In St. Paul up to some years ago we used 2-inch lead pipe, but we find that at points of very heavy pressure we continually have an expanding effect. Then we adopted the practice of putting in galvanized iron, but in our community it is not very durable. Probably the quality of the pipe was reduced years ago and we did not know the quality of some of the iron, which was very inferior. We have given that up, therefore, and are putting in brass.

W. S. PATTON: We have almost discontinued the use of wrought iron pipe. We are using now for the smaller sizes, cast-iron pipe in $1\frac{1}{4}$- and 2-inch sizes, very satisfactorily, and even where we shove the pipe across the street. We have some rather wide streets at Ashland, and we first shove the wrought iron pipe across and then enlarge the hole by shoving a little bit larger size across and then we start in and shove the cast-iron through the hole. We have 2-inch cast-iron, belt and spigot pipe underneath that paving with perfect results. We have never returned to the use of galvanized pipe, because the cast-iron pipe gives us so little trouble from electrolysis, whereas the wrought iron was eaten out in such a short time. It is not an infrequent occurrence to renew the same service line once a year, but with the cast-iron we seem to be having freedom from this trouble. If we could obtain cast-iron pipe in a $1\frac{1}{4}$- and 2-inch size, cement coated, we would have the ideal material to use in our smaller service lines.

MR. CROWLEY: What lengths of pipe do you use?

CHAIRMAN PATTON: These are, I believe, in 5-foot lengths, with two joints attached, which gives us a 10-foot length. They are made by the McWane Cast Iron Pipe Company, although there are other foundries now turning out the same kind of pipe.

Mr. Morse: We have used for a number of years the $1\frac{1}{4}$-inch McWane pipe and have found it very satisfactory. The only trouble we have had at all, which is really not the fault of the pipe, is that we make most of our service connections in the sewer connection trench. We do that because we save a great deal of money in construction. We simply place our service 4 feet in depth and dig a small trench on the side of the sewer connection trench and then we place it across. We have had perhaps two or three dozen instances in the whole four or five years that we have used that form of construction, that the $1\frac{1}{4}$-inch pipe has sheared off, but we find that it is better to take a little more maintenance cost once in a while in order to gain the economy of putting the pipe in the sewer trench.

We make some 3000 water and sewer connections each year, and of course in that way the total savings in constructions are very large.

Mr. Hanley: In your cast-iron service pipes what kind of cock do you have at the curb?

Chairman Patton: With the $1\frac{1}{4}$-inch cast-iron we can use an ordinary $1\frac{1}{4}$-inch cock. This bell and spigot pipe is supplied with short pieces if you want them, there being a nipple bent on one side and threaded on the other, in almost any kind of shape you want to get it. I believe you can get it now with the T's cast in it or you can get a full length of cast-iron with a bell on one end and threads on the other end, and you screw your T into that. It is very flexible.

Mr. Hanley: Do you use the regular lead gooseneck on that?

Chairman Patton: You can tap it. Even though you do not use those bosses, it might be that that could be tapped with the corporation cock. I am not sufficiently familiar with that to say. I am afraid you would have to use a saddle or clamp.

Mr. Lane: We put in about two miles of the $1\frac{1}{4}$-inch pipe in St. Petersburgh. We do not use the saddles. We tap the bosses where they come off the larger pipe and use a corporation cock. There is also any combination you want. They furnish threaded nipples so you can have a spigot on one end, or the bell or spiral is put on the other end.

Mr. Morris: Our method seems to be a little bit different. We make a practice of using 2-inch only rather than using the $1\frac{1}{4}$-inch. We install them along the dividing line of the property so they can take care of two service connections. The meters are being set side by side at the property line. The connection at the main is made with a double corporation cock and then a combined bell and thread piece is screwed onto the corporation pipe and the pipe connected into that fitting with a lead gasket, or rather a lead joint.

We make a great deal of use of that double connection. It saves you a great deal, although we use it in the $1\frac{1}{4}$-inch size of main pipe. We set our meters near the property line or near the curb as the case may be, and simply bring the $1\frac{1}{4}$-inch pipe from the main to the meter box. Then we make or have a riser of wrought iron, just using that piece of wrought iron in the box and set the meters in meter boxes. The two meters can be placed in one box, the two pipes coming out one from each meter, and going to the respective properties. Of course, the services to the property line are maintained by our organization and the services are separated before they enter on private property. In case of any particular trouble only one house need be shut out of water besides the one you are working on.

We do not use any curb boxes at all, using the type of meter yoke which has a cut-off in the yoke.

Do you have any shut-off on the cast-iron pipe itself at the curb?

Mr. Lane: No, no shut-off on the cast-iron pipe itself at the curb, just simply in the meter box after you have come up in the meter yoke. Do you install them in both places?

Mr. Morris: We have not found that expenditure necessary. We have had no trouble in the shutting off of the yoke itself, so we think that saving is justified. In other words, in general, it is better to take a little grief possibly on the operating side in order to make a large saving on the construction. We do that in a number of instances, just as I said a little while ago in putting the water connection in the same connection as the trench. We later have a little trouble in the connection in order to make the saving.

Chairman Patton: We use that kind of line where we require 1-inch or a little bit larger pipe. At present we are using $\frac{3}{4}$-inch Byers wrought iron galvanized pipe, and our experience has been satisfac-

tory. I believe though that it is only going to be a question of a little while until we will be using the thin walled copper pipe. That is the reason I am so interested in the present discussion.

Mr. Crowley: In St. Paul, in many cases the sewer connection will be down 20 or 25 feet. We have made it a practice for years to keep away from the sewer ditch. We try to make a straight line from the main to property line and the sewer follows the slope of the connection, so sometimes we keep on the ledge. We find this fill or deep sewer trench would be apt to pull away and loosen it. We tried to keep at just the depth of our own water main and have a solid bottom as far as possible. We have had had experiences the other way. Of course, in many cities the difference in depth between the sewer and water main is not so marked.

Mr. Morse: We have all kinds of conditions. We have very rough and some level topography. We go from tide level to 500 feet elevation, and our sewers are generally laid, where possible, at a 6-foot depth. Of course in many cases we get in deep too. We never lay the water line in the street in the same trench with the sewer, but I was speaking only of the connection.

Mr. Crowley: We follow that practice to property line.

Chairman Patton: We got into an interesting discussion in regard to meter yokes. There is something that is going to be used more and more universally. I would like to hear from Mr. Luscombe. Do you use the meter yoke or riser or place your meters in basins?

William Luscombe: We do not use the meter yokes. Practically all our meters are inside settings. It so happens that our company furnishes the gas and electricity as well as the water to the citizens of the town. It is necessary for them to go into the premises to read the gas and electric meters. For that reason it is more practical to have inside settings for water meters. The meters are placed near the basement floor, where the pipe enters the building, and from that pipe there is a riser pipe from the basement ceiling joists which passes on to the various parts of the building. There is always a stop cock in the service pipe just at the meter inlet for turning off and draining the pipes.

Donald H. Maxwell (Chicago, Ill.): I am young in this game and I would like to ask some of the older heads why you use lead goosenecks in connection with galvanized and wrought iron and steel pipe. Why would it not be just as well to tap the pipe into the main?

Mr. Luscombe: It is put there to give flexibility to your service line. In case of a slight contraction or expansion also, it will not cause any pull on the joints to weaken or produce leaks.

Mr. Maxwell: Would it not be necessary to use that lead gooseneck with the copper or brass pipes?

Mr. Luscombe: We have never used copper pipes. I am not prepared to say.

Chairman Patton: It would not be necessary to use a gooseneck with copper pipe because you can create a gooseneck yourself. After you leave the main you can easily bend it into a gooseneck to take care of any expansion or contraction.

Mr. Lane: You can bend the copper pipe, just the same as the lead. We are doing away with the lead. I might say we do not have to go very deep so we use a concrete meter box with a meter and curb cock inside the box.

Chairman Patton: Mr. Lane, in setting your meters you simply bend the copper pipe, don't you? The pipe is of sufficient strength to support the meter.

Mr. Lane: We start out from the main with the cast-iron pipe, make the tap there and gradually rise up so we have our meter setting 8 inches below the surface. We put our meters in one corner of the parking and the parking is generally grassed over. We have the concrete meter box, with the box painted green. In this territory it lasts as long as cast-iron, and it makes a simple and cheap construction. It would not apply in many places.

Mr. Patton: I wonder, on a deeper setting than they have in Florida, whether we could bend the pipe up and run it directly into the meter yoke. So far we are using an L at the end of the pipe and

are still using the wrought iron riser. I should like to do away with that if there is rigidity enough in the copper pipe.

Mr. Hanley: You could use brass pipe for that purpose, couldn't you?

Mr. Lane: Yes, we could, but I do not see any particular advantage in using brass pipe. In case of deterioration of wrought iron pipe it is so easy to get at, and it does not seem it would be necessary to go to the expense of short brass pipe. I think in case of repairs we would shut off one block of the distribution system.

Mr. Hanley: If you had this short life pipe inside your curb box then I think it would be all right, but if any of this short life pipe is outside of the curb box it looks as though you would have to go to the corporation cock.

Mr. Lane: We would not do that. We would shut down one block of the pipe system.

Mr. Hanley: You could not do that in a great many cities.

Mr. Lane: But at any rate there are so many galvanized iron services on the system, I do not think we would take much account of the short length in the meter boxes themselves.

Mr. Crowley: One of the great advantages is that you can curve the copper so it will allow for slippage and your pipe will adjust itself for the settling of the ditch. In our city we lay them 7 feet deep and sometimes there is quite a settlement, depending on the kind of fill. By making this allowance it will adjust itself to any reasonable settling of a ditch. Of course a rigid pipe would hardly do that.

Mr. Hanley: It appears to me from what I have heard that the question of service pipes might be divided into two classes. One would be corroded and the other a non-corroded, such as copper, brass or lead. Of all classes of iron or steel pipe it looks like the cast-iron is the most durable and pretty nearly as cheap as the other. If you have conditions where you require 2- or 3-inch services, it looks like the proper procedure would be to put in cast-iron pipe. If you

have conditions that require service of 1-inch or $\frac{3}{4}$-inch pipe, then the question is to put in either brass, lead or copper. I would think that the question of a 1-inch and over sizes is pretty well solved, but the question of other sizes seems to me to be the cause of a difference of opinion. Most people are swinging from the lead to the copper or brass.

Chairman Patton: I believe that expresses the current opinion on the question. Is there any further discussion?

Chairman Patton: The next question is "Have you found by actual experience that wrought iron service lines out-last steel?" That is an old, old question. Have you had any actual experience on this? Have you ever buried an iron pipe and a steel pipe about the same time and have you ever taken the trouble to tear it in two?

Mr. Morris: Everyone has made this observation, that all of our service piping, before the advent of the Bessemer process, was of puddled pure wrought iron pipe. Our general experience is that those pipes are much older than the pipes laid in the later 90's and up to 1910, say, which are generally in better condition than are the pipes laid at a later date. On that basis, we of the water system adopted the pure iron pipe made by Byers, Greeley & Company, or any of the companies putting out pure wrought iron pipe.

R. C. Beam: I was in Mr. Cotter's office about a month ago. He is water works superintendent of Springfield, Ohio, and he showed me three samples of pipe. He is a man sixty-five years old and has had a world of experience. One sample was cast-iron, one wrought iron and one steel galvanized, with no galvanized iron. The cast-iron was in perfect condition. There was absolutely no corrosion taking place on either the inside or the outside. The wrought iron was not in so good condition; there seemed to be pitting. The steel that was galvanized was pitted all the way through.

Mr. Cotter stated the cast-iron had been in service twenty-seven years; the wrought iron a similar amount of time, and the steel about three years. He has seen those three pipes come and go, and that has been his experience.

Mr. Voskin: We have considerable steel pipe in our service, some of it about twenty years. However, it all has a protective coating on the outside. I mean that, in addition to the dipping, it has a sort of burlap wrapping around it. A recent examination was made which discloses that it is in practically as good condition as it was twenty years ago. Ours is sandy soil, and it is rather difficult to estimate the life of pipe, but only a slight deterioration has taken place so far.

Chairman Patton: What was the diameter of the pipe?

Mr. Voskin: It ranges from 3 to 12 inches.

Mr. Crowley: Three-quarter-inch is now what we use in St. Paul. Sometimes there are four and even as high as six flats. Another man comes in and cannot get along with one inch. He must have a 2-inch for six flats.

Mr. Hanley: Speaking from the railroad point of view, we have found when we ask for a 4-inch meter we usually get a 2-, so I think you fellows have that down pretty well.

Mr. Morris: We charge a sliding scale of minimums which make those who want larger service pay all the costs, so that we do not worry so much if they want larger service. We have a minimum charge, based not alone on the interest, depreciation, maintenance and operation and meter service, but also on the increased amount of unregistered water that will take place with the larger service. The larger service they get the harder they are hit on the monthly cost.

In general, most of our consumers have the $\frac{3}{4}$-inch meters. We will install a 1-inch meter for anybody who wants it. In general, those who have lawn sprinkler systems, have the ground completely piped with sprinkler sets, with 8-, 10- or 12-foot centers, so they can turn on the water. They are the ones who want the larger service for domestic consumption. Our rule is that anyone who wants a service connection larger than 1-inch for domestic purposes, makes application to our domestic department and they decide what size they can have. The meter service clerk is not authorized to issue anything larger than 1-inch in diameter until it is referred to the engineering department, where it is determined consistent with the size of the ground.

Mr. Morse: We are in much the same situation as Pasadena. We do not worry quite as much as we would if we did not have a service charge. We charge four dollars a year as a true service

charge for a $\frac{5}{8}$-inch meter, seven dollars for $\frac{3}{4}$-inch and twelve dollars for 1-inch, up to \$360 a year for the 8-inch meter. Most of the residences have the $\frac{5}{8}$-inch meter, but anybody can make an application for any size wanted. If the application is all out of reason for its service, we simply try to argue the matter out with the applicant. We have found both plumbers and architects have given us a great deal of trouble. They always seem to want a meter of the same size as the house connection. Very often we gain the point with the applicants by saying we will put in a $\frac{5}{8}$-inch meter, and, if it does not do what they want, we will put in a $\frac{3}{4}$-inch meter. We tell them that they had better try to save the cost. We seldom have anybody come back for the larger size meter. Those who do come back are generally those who use the flushometer. That is giving us a greater amount of trouble now than it used to. I hate to bring it up in this meeting, because I know what it generally leads into.

Mr. Ruskin: I believe the size of the meter and the size of the tap are somewhat determined by the pressure in the system. With us we carry about 50 pounds domestic pressure for domestic service. Almost all of our meters are of the $\frac{5}{8}$-inch size. We do not have any trouble except in special cases where they have the flushometer toilets. For larger sizes application is made and any application that is sought is numbered. The number, kind and fixtures and other uses to be made of the water are noted. From that information we determine what we consider will be the proper size meter for the place. Meters are read monthly and by checking the monthly consumption, in some instances where special uses or miscellaneous use is made of the water, by getting what you might term the peak load when industries or enterprises are carried on in full blast, one can determine whether the proper size meter is installed for that service.

There is a rather interesting device in the exhibit room. It is a flow recorder. It is a mechanical device so that the chart indicates the rate of flow through the meter throughout the twenty-four hours. If that is properly developed and not too complicated, it should be quite an aid in determining the proper size and type of meter for various classes of service.

Chairman Patton: It seems to me that what we need is a curb workout so that taking the number of occupants of an apartment

building and the number of fixtures, we could pretty accurately determine the amount of water that is going to be required. Our chief difficulty though lies with the architects, who invariably specify from 50 to 100 per cent larger meters than are really required.

Mr. Crowley: I find the architects do not consider it is worth while to come to the office to get any information on the subject. I have been trying to keep silent on the question, because we have been rather perplexed trying to determine by some such scale as this. We have a clerk to determine the requirements for each fixture. He gets the total and discounts it by a certain per cent according to the pressure.

Mr. Hanley: In Chicago I have had considerable experience in negotiating with the city water department in services for the railroad. I am familiar with the department's ruling. They feel bound only to deliver the water at the surface of the ground at your premises. For instance, this hotel, sixteen stories high, and the Morrison, fourteen stories high, have roof tanks or house pumps. The city is under no obligation to give pressure to such great heights. In other words, the ordinance is that they shall give water to open tanks, and from that open tank it is elevated to whatever height you wish. I presume that such a condition would prevail in St. Paul, but in smaller towns I do not know.

Mr. Crowley: We try to keep a minimum of 30 or 40 pounds for fire protection. We hardly feel that we have fire protection under forty pounds.

Mr. Hanley: If you go down in the engine room in the basement of this hotel, very likely you will find an open service tank. The water comes into that open tank. There is no open connection. A reservoir receives the water below. It is pumped from the open tank to the higher floors. They do a little better than the city of Chicago, giving 20 or 35 pounds of pressure. I have had occasion to remonstrate with them in the various outlying districts when we take water. I have always been told that the city does not feel obligated to do your pumping for you. They will furnish the

water and if you cannot get along with their pressure you can put in a tank and pump it. That is the case 20 miles from the heart of the city. While they are extending the mains and getting larger connections now, they are constantly improving. I know in the last ten or fifteen years, the outlying users have had considerable difficulty on account of low pressure. I have just finished a trip through this tunnel this morning and I see where they are putting in a 16-foot tunnel. I know they are making a great effort to get an adequate water supply.

SOCIETY AFFAIRS

MINNESOTA SECTION

The Minnesota Conference on Public Utilities met in a joint session with the Minnesota Section of the American Water Works Association in one of the company rooms of the Minneapolis Armory, Minneapolis, Minnesota, at 10 a.m., June 15, 1927.

Meeting was called to order by Felix Seligman, Chairman of the Minnesota Section.

A paper on "Elimination of Odor and Taste From Public Water Supplies by Aeration" was presented by R. A. Thuma. Questions were asked by Mr. Bang and Mr. Gallaher.

Following Mr. Thuma's paper, J. W. Kelsey, gave a paper on "Copper Service Pipes."

In Mr. Kelsey's paper he outlined St. Paul's ordinance in regard to installation and maintenance of the service pipes by the city in which they run service pipes to property lines and maintain them for a period of thirty years for a fee of $39 on a $\frac{3}{4}$ inch pipe. This price is standard on 66 foot streets. The work is let to contractors who must furnish bond and installation is made under inspection.

Questions were asked by J. A. Jensen, F. E. Patterson and Mr. Bang.

Mr. Gallaher of Aluminate Sales Corporation, Union Stock Yards, Chicago, Ill., followed with a short talk on sodium aluminate.

The Minnesota Section stood adjourned until 2 p.m., June 16, at which time the minutes of the last meeting were read.

Resolutions offered by the Illinois Section were discussed. Mr. Jensen stressed the need of some plan to prevent the overloading of water supplies with pollution. Mr. Jensen made a motion that we adopt the resolution and let it stand. Motion carried.

Chairman Seligman announced the report of the nominating committee. G. C. Pruett, Chairman; J. W. Kelsey, Vice Chairman; D. A. Reed, Trustee. On motion they were declared elected. The executive committee reappointed R. M. Finch, Secretary.

Members and visitors present numbered 34. On motion the conference adjourned until the 1928 convention.

DISCUSSION

EXPERIENCE WITH TURBINE TYPE WATER METERS

Our experience at Charleston with the turbine type water meter has been rather annoying at times. The difficulty has been that the meters over-registered due to accumulation on the vanes of the turbine, so that the loss of head through the meter increased, and then, in order to discharge the same quantity of water, the speed of the turbine wheel is increased. We have had them show as much as 30 per cent over-registration within a few days after being installed. Of course, this is an extreme case where yarn was working out of the joints in the mains and lodging on the vanes. Until recently, in all our turbine type meters, the water passed through the sides of the top and bottom of the piston and then discharged through the center of the piston. Possibly the single type runner is not so susceptible to over-registration from the cause above described, but we have had no experience with this type.

Recently we have installed in our turbine type meters a piston of a new design and so far the meters appear to be registering properly. The chief difference in the design consists of a casing around the propeller of the piston so that all of the water must enter both ends of the piston and impinge against the turbine blades at right angles to the plane of the blade; furthermore, the flutes of the wheel or blades are beveled toward the periphery so that when material tends to lodge on the blade, it is worked out toward the periphery and through the meter. We are not satisfied that this modified type of piston is going to be the solution of our trouble, but we hope so. The over-registration in nearly every case has been due to fibrous material from the joints in the main or from flax packing that has escaped from the pump. We do not use fish traps or screens in front of these meters, since in our opinion this protective apparatus imposes too much resistance to the flow of water.

J. E. Gibson.[1]

[1] President, American Water Works Association; Manager and Engineer, Water Department, Charleston, S. C.

ABSTRACTS OF WATER WORKS LITERATURE

Frank Hannan

Key: American Journal of Public Health, **12:** 1, 16, January, 1922. The figure 12 refers to the volume, 1 to the number of issue, and 16 to the page of the Journal.

Spectrographic Analyses of Residues of Mineral Water. I. Water of Salsomaggiore. C. Porlezza and A. Donati. Ann. chim. applicata, **15:** 535–42, 1925. Chem Abst., 20: 1370, May 10, 1926. Spectrographic examinations and chemical analyses were made of Salsomaggiore water. No element was found by one method and not by other. Spectrographic determination of barium (method described) indicated content of 0.0162 p.p.m. Previous chemical examinations reported only traces, no quantitative data being included. Results indicate that spectrographic examination is as reliable as chemical analysis for identifying elements present in residue of water.—*R. E. Thompson.*

Carbonates and Bicarbonates in the Water of the Nile. V. M. Mosséri. Bull. inst. Égypte, **7:** 155–62, 1925. From Chem. Abst., **20:** 1479, May 10, 1926. Data of carbonate and bicarbonate content.—*R. E. Thompson.*

Chemical and Chemico-Physical Researches on the Saline Water of S. Venera (Acireale) which Contains Bicarbonates, Hydrosulfides, Boric Acid, Bromine, Iodine and Lithium. R. Nasini, C. Porlezza and A. Donati. Ann. chim. applicata, **15:** 484–518, 1925. From Chem. Abst., **20:** 1480, May 10, 1926.—*R. E. Thompson.*

Chemical Analysis of Capvern Water. Ch. Lormand. Compt. rend., **182:** 404–6, 1926. From Chem. Abst., **20:** 1480, May 10, 1926.—*R. E. Thompson.*

The Hydro-Electric Plants of Rempen and Sieben in the Canton of Schwys, Switzerland. The Barrage Reservoir of Wäggital. A. Bidault des Chaumes. Genie civil, 87, 241–5, 1925. From Chem. Abst., **20:** 1481, May 10, 1926. Most important development in Switzerland. Reservoir will contain 148 million cubic meters, retained by dam 100 meters high. Fall utilized is 240–260 meters.—*R. E. Thompson.*

Modern British Practice in Water Softening. V. Zeolite or Base-Exchange Methods of Water Softening. D. Brownlie. Ind. Chemist, **2:** 61–4, 1926; cf. C. A., 20, 637. Chem. Absts., **20:** 1479, May 10, 1926. Advantages of zeolite water softening (doucil, kenzelite, permutite) are: (1) zero hardness,

(2) ease of dealing with all quantities of water, (3) no sludge, (4) simplicity of plant, (5) operation under pressure, (6) small floor space, (7) no moving parts, (8) alkali beneficial in boiler water and for laundry and bleaching plants, (9) easy control of exact hardness. Disadvantages are: (1) Alkaline water is cause of foaming and priming, and at pressures above 150 pounds per square inch tends to render boiler plate brittle. Such water is objectionable for drinking and cooking, also in dyeing, brewing, and other fermentation processes. (2) The zeolite disintegrates. (3) Carbon dioxide has solvent action on zeolite. (4) Acids act on zeolite. (5) Iron in water precipitates on zeolite as ferric hydroxide and lessens effectiveness and rate of regeneration. (6) Traces of oil in water gradually cover zeolite with fine film and render it useless. (7) Suspended matter must be first removed. (8) Size of plant depends on hardness of water. (9) There is nothing to prevent unsoftened water passing through filter when zeolite is exhausted. (10) Zero hardness is not necessary since 1° or 2° of hardness does not cause precipitation of magnesium and calcium salts of fatty acids. These remain in solution and act as detergents. Zeolite methods are ideal for water of moderate hardness, not over 12–15° total with little or no temporary hardness. For very hard water with little permanent hardness the lime-soda method is infinitely superior.—*R. E. Thompson.*

Stream Pollution. KENNETH ALLEN. Proc. Am. Soc. Civil Eng., 52, 520–31, 1926. From Chem. Absts., **20**: 1480, May 10, 1926. Symposium of results of Metropolitan Sewerage Commission. Standard of cleanliness proposed for New York Harbor.—*R. E. Thompson.*

The Presence of Iodates in Well Water. C. F. HICKETHIER and ALBERTO JACOBUCCI. Z. anal. Chem., **67**: 129–33, 1925. From Chem. Abst., **20**: 1480, May 10, 1926. In examination of waters from Argentine Republic, presence of nitrites was indicated by testing with Trommsdorff's reagent, but subsequent investigation showed that test was due to iodates. Reactions of Ilosvay v. Ilosva and Riegler are most reliable and sensitive tests available for nitrite.—*R. E. Thompson.*

Relation Between Stream Pollution and Extent of Sewage Treatment Required. J. K. HOSKINS. Proc. Am. Soc. Munic. Improvements, **31**: 317. From Chem. Abst., **20**: 1481, May 10, 1926. Point of maximum concentration of B. coli occurs 10 to 15 hours in summer and 15 to 30 hours in winter below sewer outlet. Bacterial decrease is more rapid in summer than in winter. It is possible by knowing maximum concentration to predict number of B coli remaining in stream at stated intervals of time and distance from sewer outlet. Permissible limit of B. coli in raw water to be purified is 1000 to 1200 per cubic centimeter. B. coli per cubic centimeter permissible at maximum concentration can then be calculated, considering time of flow from point of contamination to water plant.—*R. E. Thompson.*

Soaps as Integral Water-Proofings for Concrete. A. H. WHITE and J. H. BATEMAN. Proc. Am. Concrete Inst., 1926, (preprint). From Chem. Abst.,

20: 1506, May 10, 1926. Soaps added in concrete mixer are effective in preventing absorption of water by capillary action—as little as 0.05 per cent fat acid on basis of weight of concrete being sufficient. Strength is not impaired by such small quantities of soap provided concrete is kept damp continuously until it has attained desired strength, and provided soap has not caused foaming and entrainment of air. Soaps will not prevent penetration of water through cracked concrete, but will retard penetration of water into dry concrete. If concrete is kept damp until properly cured there should be only slight diminution in strength due to water-proofing, and conditions may arise in service where strength is increased.—*R. E. Thompson.*

Purifying Water By Use of Barium Silicate (to Remove Hardness). A. L. GRANT. U. S. 1,574,477, February 23. From Chem. Abst., **20**: 1482, May 10, 1926.—*R. E. Thompson.*

Apparatus for Purifying Water By Ozone. H. B. HARTMAN. U. S. 1,574,389, February 23. From Chem. Abst., **20**: 1482, May 10, 1927.—*R. E. Thompson.*

Effect of Lime on Concrete Products. P. C. CUNNICK. Proc. Am. Concrete Inst., 1926, (preprint). From Chem. Abst., **20**: 1506, May 10, 1926. In general, results of nearly 2000 specimens varying in mix, lime content, age, curing conditions, etc., indicate that (1) appearance of product is improved by all percentages of lime; (2) up to 40 per cent by weight, hydrated lime gives an average increase in strength of approximately 1 per cent for each pound of lime added per sack of cement—all percentages of lime tested showing increase in strength from 28 days to 6 months; (3) absorption is increased, as determined by standard immersion method, but not increased as determined by impounding water on one face; (4) permeability as determined by impounding water on one face is eliminated by using 20 per cent or more of hydrated lime; and (5) penetration of dampness into product decreases as lime is increased.—*R. E. Thompson.*

High-Test Bleaching Powder: Calcium Hypochlorite and Basic Calcium Hypochlorite. SABURO URANO. Trans. Am. Electrochem. Soc., **49**: (preprint), 1926. From Chem. Abst., **20**: 1965, June 20, 1926. U. succeeded in obtaining calcium hypochlorite and basic calcium hypochlorite in crystalline state, using bleaching powder as starting material. These compounds are more active and more stable than bleaching powder. Calcium hypochlorite and calcium hydroxide combine to form crystalline $Ca(OCl)_2 \cdot 2Ca(OH)_2$ for a definite condition of liquid phase. This compound gives bleaching powder of higher available chlorine (40 to 48 per cent) and of greater stability than ordinary bleaching powder. Calcium hypochlorite solution free from calcium chloride can be obtained by dissolving the basic salt in water.. By evaporation of the hypochlorite solution in vacuo (25–50 mm. mercury, 30 to 40°), U. produced calcium hypochlorite in crystalline state purer than that made by older processes. By drying the crystalline hypochlorite the highest test bleaching powder, containing 90 to 95 per cent available chlorine, was obtained.—*R. E. Thompson.*

Geophysical Methods in Ground and Water Studies. E. Link and R. Schober. Gas u. Wasserfach, **69**: 225–8, 1926. From Chem. Abst., **20**: 1971, June 20, 1926. Various physical methods employed in locating ground water outlined.—*R. E. Thompson.*

Oxidation in Sea Water. H. W. Harvey. J. Marine Biol. Assoc., **13**: 953–69, 1925. From Chem. Abst., **20**: 1997, June 20, 1926. "Deep water" from English Channel contains a catalyst which increases rate of oxidation of easily oxidizable substances such as pyrogallol and quinol. Decomposition of hydrogen peroxide is also catalyzed by deep water. Suggested that catalysts are organic compounds of iron and that inactivity of surface water is due to presence of oxidizable organic matter. When these substances are oxidized by hydrogen peroxide the surface water becomes more active.—*R. E. Thompson.*

Nephelometric Determination of Calcium and Magnesium. II. Leonia Kriss. Biochem. Z., **162**: 359–65, 1925; cf. C. A. **20**: 1041. From Chem. Abst., **20**: 1772, June 10, 1926. In 50 per cent alcohol, calcium and magnesium can be determined by precipitation with ammonium ferrocyanide. Calcium alone can then be determined by precipitation with sodium sulforicinate. Method suitable for water analysis.—*R. E. Thompson.*

A Method for the Microscopic Analysis of Sediments. G. Lundquist. Geol. För. Förh., **48**: 48–60, 1926. From Chem. Abst., **20**: 1779, June 10, 1926. Method described for examination of sediments, mixed with water and glycerol, under microscope with Nietz micrometer attachment to determine size of such constituents as calcite, sand, loam, pyrite, coarse detritus, fine detritus, pollen, spores, diatoms, etc.—*R. E. Thompson.*

Opinion and Decision of the Railroad Commission of Wisconsin in Reinvestigation of Pollution of Flambeau River at Park Falls. Decided February 20, 1926. Pub. Health Eng. Absts., March 20, 1926. From Chem. Abst., **20**: 1876, June 10, 1926. Summary of evidence presented before the commission regarding stream pollution by pulp and paper waste and its effect of fish life. Bibliography included.—*R. E. Thompson.*

Corrosion Due to Magnesium and Calcium Salts. D. C. Carmichael. Power Plant Eng., **30**: 411, 1926. From Chem. Abst., 20: 1876, June 10, 1926. Dissociation of calcium and magnesium chlorides and nitrates by high temperatures and pressures causes formation of acids which corrode boilers. Formation of scale prevents discovery of corrosion until cracks are formed.—*R. E. Thompson.*

Operation of Rapid Sand Filtration Plant of Cambridge, Mass. Melville C. Whipple. Water Works, **66**: 121–23, 1927. Because of the necessity for economy, the wash water was returned to the coagulation basins. The coagulation basin was unable effectively to remove this additional load of impurities, so chlorination of the raw water was adopted. This did not overcome

the detrimental effects of adding the wash water to the coagulation basins. An experimental wash water discharge line to the sewer was installed, and after trials had proved the advantages, discharging to the sewer was adopted. Difficulties with clogging of a $2\frac{1}{2}$-inch alum feed line led to the adoption of periodical flushing from a pressure line and treatment with chloride of lime as the best routine treatment. New sand was added to the beds which increased the effective size from 0.38 to 0.45 mm. and reduced the uniformity coefficient. This has increased the filter runs somewhat, and has shown no detrimental effect on the filter effluent. Once a year each filter is allowed to stand overnight with 0.2 per cent solution of NaOH. A record of the quality of the water is given and the changes which have taken place in the water of Fresh Pond since the storage time has been increased are described.—*C. C. Ruchhoft* (*Courtesy Chem. Abst.*).

New Water Supply of Kingston, N. C. John E. Weyher. Public Works, **58**: 93–4, 1927. The old supply, which had become inadequate, consisted of 12 wells of various sizes from 3-inch to 10-inch and from 290 to 510 feet deep, with a total capacity of 380 g.p.m. A new well was drilled having a 38-inch casing the first 90 feet, a 24-inch casing to the 190-foot depth, and an 18 inch casing from the surface down 302 feet. Below this it has an 18 inch shutter screen in a 48-foot sand stratum. The sand and mud in the water bearing stratum were replaced with unifom size round filter gravel, and a total filtering area at the point of separation of approximately 490 square feet was obtained. The well was equipped with a Layne deep well turbine pump directly connected with a Westinghouse motor and delivered under test 871 g.p.m. with a drawdown of 46 feet.—*C. C. Ruchhoft*.

Water Supply of Anacartes, Wash. Wm. B. Short. Water Works, **66**: 125–6, 1927. The new water supply of Anacartes is pumped from Lake Campbell to Whistle Lake and again to the filter plant. The water is treated with alum, aërated, settled, filtered, and chlorinated. Both pumping stations, the equipment of which is described, are operated by remote control from the filter plant, which has 4 gravity type filters 12 feet x 12 feet, with a capacity of 500,000 g.p.d. The cost of filtration is $7.87 per million gallons, and the total cost to the consumer is $36.43 per million gallons.—*C. C. Ruchhoft*.

Apparatus for Measuring Turbidity and Colour of Water. W. Olszewski. Chem. and Ind., **45**: 50, Dec. 10, 1926; Chem. Ztg., 1926, **50**: 694. The water under examination in a tube 20 cm. long is compared with distilled water in a similar adjacent tube by means of a half-shade photometer. The colours of the two are matched by the insertion of suitable coloured glasses, while the relative turbidities, against Ostwald's normal white, are determined by varying the amount of light passing through the distilled water by means of a graduated slit. (F. R. E.)—*A. M. Buswell*.

Treatment of Water for Use in the Manufacture of Artificial Silk. Brysilka Ltd., and F. W. Schubert. (E. P.262, 369; 4.8.25). Chem. Ind., **46**: 7, Feb. 18, 1927. Water is fed into a de-aërating chamber in which a vacuum is main-

tained, the dissolved air being thus liberated and part of the liquid vaporised with consequent cooling of the system. (B. P. R.)—*A. M. Buswell.*

Physico-Chemical Processes Involved in the Removal of Manganese from Drinking Water. I. Adsorption of Bivalent Manganese by Manganese Dioxide. J. Tillmans, P. Hirsch, and F. Häffner. Chem. Ind., **46**: 11, March 18, 1927; Gas u. Wasserfach, 1927, **70**: 25–30, 58-63. A study has been made of the adsorption of manganese by manganese dioxide from solutions of manganous sulphate which contained also a carbonate-bicarbonate buffer mixture. Equilibrium is attained after about one hour's shaking. The adsorption is reversible and increases with rise of temperature. It is concluded that the manganous ion is adsorbed directly, an equivalent quantity of sulphuric acid being liberated. The amount adsorbed for a constant pH varies with the equilibrum concentration of the solution according to the Freundlich adsorption isotherm, whilst for a constant end concentration the amount adsorbed is a linear function of the pH value. (A. B. M.).—*A. M. Buswell.*

Chemical Tests for Fecal Impurities in Drinking Water. R. Schmidt. Chem. Ind., **46**: 11, March 18, 1927; Gas- u. Wasserfach, 1927, **70**: 77. The indican test proposed by Jolles (B., 1921, 59A) is definite, but in some cases the extreme dilution of the impurity, or the possible adsorption of indican during filtration of the water through the soil, renders uncertain the value of a negative result with this test. Better suited to the purpose is the bacteriochemical indole test as described by Gersbach (Zentr. Bakt. 1922, I, **88**: 145). (A. B. M.).—*A. M. Buswell.*

Potassium Permanganate Absorption, "Chlorine Number," and Chlorination of Water. W. Olszewski. Chem. Ind., **46**: 3, Jan. 21, 1927; Z. angew. Chem., 1926, **39**: 1309–1310. Determinations of the "chlorine numbers" and permanganate absorptions of a series of artificially contaminated waters confirm the results of Froboese and Keiser (cf. B., 1926, 222). For the examination of drinking waters the importance is emphasised of the ratio of the permanganate absorption to the chlorine number in conjunction with the bacteriological examination for the detection of contamination by protein degradation products. For the control examination of swimming-bath waters the permanganate absorption and chlorine number should both be determined. (E. H. S.).—*A. M. Buswell.*

Extreme Lability of Certain Mineral Waters. W. Kopaczewski and A. de M. Sarmento. Compt. rend., 1927, 184, 109–111; Chem. and Ind., **46**: 11, March 18, 1927. The variations with time of the pH value, degree of ionization, titratable alkalinity, and iron content of a meso-saline cold water from Vidago, containing 5.33 per cent and 1.13 per cent of sodium and calcium bicarbonates respectively, have been studied. (J. G.).—*A. M. Buswell.*

Producing a Protective Coating in Water Tubes for the Purpose of Preventing Incrustations. C. Bücher. (E. P. 260,233; 5.10.26. Conv. 21.10.25): Chem. and Ind., **46**: 15, April 15, 1927. Sufficient calcium hydroxide solution is added

to a drinking water supply containing free or partly bound carbonic acid to produce calcium carbonate. This forms over a period of months a protective chalk lining in the iron pipes, while the hydroxyl-ion concentration is increased above the neutrality point without exceeding the palatable limit. (H. H.).—*A. M. Buswell.*

Behaviour of Active Chlorine Preparations Towards Organic Materials. E. Remy. Chem. Ind., **46**: 15, April 15, 1927; Biochem. Z. 1927, **180**: 97–104. The following antiseptics are placed in decreasing order of their ease of decomposition by organic matter: antiformin (alkaline sodium hypochlorite), hypochlorite (aqueous solution of sodium hypochlorite), caporite (calcium hypochlorite), multisept (mixture of equimolecular amounts of succinic acid and bleaching powder), pantosept (sodium dichlorosulphonamidobenzoic acid), chloramine (sodium p-toluenesulphonchloroamide), and magnocide (basic magnesium hypochlorite). (P. W. C.).—*A. M. Buswell.*

Comparative Chemical Results of Slow and Rapid Filtration (of Public Water **Supplies**). F. Egger. Chem. Ztg., 1927, **51**: 94; Chem. Ind., **46**: 15, April 15, 1927. Clarification with aluminium sulfate, followed by rapid filtration, is compared with slow sand filtration in the case of river and lake water forming the Stuttgart supply. No advantage was found in adding more than 20 mgm. of aluminium sulfate per litre; $2\frac{1}{2}$ hours was period allowed for flocculation. Oxygen absorption was reduced by 40 per cent, being rather better than with sand filtration; the chlorine figures were similar in the two methods. The bacterial counts in the former method are less satisfactory and chlorination is advisable. Free carbon dioxide, present in the soft lake water, interferes with flocculation, but can be removed by agitation. The taste is considered to be better with the rapid filtration treatment. (C. I.).—*A. M. Buswell.*

Purification of Water. Établ. Phillips and Pain. (F. P. 608,171; 28.3.25). Chem. Ind., **46**: 15, April 15, 1927. A mixture of water with part of the solution of sodium compounds from a base-exchanging purifying plant is treated with lime to precipitate carbonates and bicarbonates. (L. A. C.)—*A. M. Buswell.*

Critical Review of the Methods of Analysing Water, Sewage, and Effluents, with Suggestions for their Improvements. J. W. H. Johnson. Analyst, 1927, **52**: 128–142; Chem. and Ind., **46**: 17, April 29, 1927. Modification of the fundamental organic nitrogen and oxygen-absorption tests are suggested: (1) A modified Kjeldahl process in which nitrites or nitrates do not interfere; (2) an albuminoid nitrogen process carried out under strictly controlled conditions, and with results in relatively close agreement with practical requirements; all acid oxidation processes are condemned. (3) Modification of the Royal Commission test which gives definite results strictly comparable inter se. The results so far recorded of this test are largely the outcome of unnatural conditions, and curves obtained should be strictly rectilinear. (D. G. H.).—*A. M. Buswell.*

Dissolution of Lead by Water in Pipes. A. Farine. Schweiz. Chem.-Ztg., 1927, 29–32; Chem. Ind., **46**: 17, April 29, 1927. Under similar conditions, distilled water saturated with air, distilled water containing (a) air and carbon dioxide, (b) air and sodium bicarbonate, (c) air, sodium bicarbonate, and free carbon dioxide, when passed at a fixed rate through a tube packed with lead shavings, dissolved, respectively, 110, 10.5, 0.6, and 1.0 mgm. of lead per liter. It follows that sodium bicarbonate exerts a strong protective action which is less strong in the presence of free carbonic acid. The results may be explained by the use of physico-chemical conditions, which indicate that in the presence of insoluble lead carbonate the concentration of the lead dissolved is directly proportional to that of the carbonic acid and inversely proportional to the square of the concentration of the bicarbonate. (W. T. L.).—*A. M. Buswell.*

Notes on Water Analysis. D. Burton and J. K. Haslam. Chem. Ind., **46**: 12, 111–4 T, March 25, 1927. The methods for determining temporary, permanent, and magnesia hardness are briefly reviewed in the light of recent literature. Sources of error in determining magnesia hardness are pointed out and a procedure suggested to minimize them. A bibliography of 55 references is appended.—*A. M. Buswell.*

Volumetric Determination of Sulfate in Drinking Water. A. Bahrdt. Z. anal. Chem., 1927, **70**: 109–119; Chem. Ind., **46**: 13, April 1, 1927. To remove the metallic ions in the water a small quantity of sodium hydrogen carbonate is added (to neutralize any acidity) and 300 cc. are filtered through 10 g. of washed sodium permutit contained in a small bulb tube. The filtrate contains only alkali metals together with all the sulfate ions; 200 cc. are neutralised with 0.1 N-hydrochloric acid using methyl orange as indicator and 1 cc. excess of acid is added. After boiling to expel carbon dioxide, 10–30 cc. of 0.1 N-barium chloride solution are added to precipitate the sulfate, an aliquot part of the filtrate is neutralised exactly with sodium hydroxide, and the excess barium chloride titrated with 0.1 N-potassium palmitate using phenolphthalein as indicator. The palmitate solution is standardised against the barium chloride solution and is prepared by adding a 16 per cent solution of potassium hydroxide in propyl alcohol to a warm mixture of 26 g. of palmitic acid, 500 cc. of propyl alcohol, 250 cc. of water, and 0.1 g. of phenolphthalein until a faint pink colour is obtained, filtering, and diluting to 1 litre. The permutit may be regenerated after use by washing with 5 per cent sodium chloride solution then with cold water. (A. R. P.).—*A. M. Buswell.*

A New Specific Color Reaction for Magnesium and a Simple Colorimetric Method for the Determination of Traces of Magnesium. I. M. Kolthoff. Chem. Weekblad, 24: 21, 254–5, 1927. The behavior of titan-yellow as acid-base indicator is described; its composition given; its reaction with Mg treated with considerable detail. The paper concludes with a summary in English, as follows. Titan-yellow is a specific and very sensitive indicator for the detection of magnesium. To 10 cc. of the solution are added 0.2 cc. of a solution of 0.1 g. indicator in 100 cc. water and 0.25 to 0.5 cc. of 4 N sodium hydroxide. In the presence of magnesium the yellow color changes to red. Sensitivity

0.2 mgm. Mg per litre. Calcium salts deepen the red color. The reaction is very suitable for the colorimetric determination of traces of magnesium in, for example, tap water. The best color scale is obtained with solutions containing 4 to 0.4 mgm. Mg per litre. If the solution to be investigated contains calcium, the color standards are prepared in solutions of magnesium which contain about 100 mg. calcium per litre.—Aluminium and tin have a disturbing effect.—Zinc can be made harmless.—*Frank Hannan.*

NEW BOOKS

CO_2 Meters (Electrical). Leeds and Northrup Company, Bulletin 781, 1927. An electrical CO_2 meter, based on the thermal conductivity method, has been developed for boiler room use. In the thermal conductivity cell the construction of the gas passages makes the flow of gas through the cell itself independent of the rate of flow in the sampling line. Gas is drawn through the cell by a convection current set up by the heat of the platinum wire, which is held at practically constant temperature. The standard gas chamber and flue gas chamber are mounted in same metal block, so that they are at substantially the same temperature. With exception of platinum wire, all metal parts exposed to flue gas are heavily gold plated to protect them against corrosion. Flue gas passes through primary filter to water-sealed drain, then to calcium chloride drier. The gases then go to the cell through a porous earth thimble, to remove any remaining dirt, moisture or acid mist. Bulletin also contains discussion on economic significance of excess air, and curves showing control of combustion, effect of hydrogen in fuel, excess air and flue gas temperature and loss due to excess air.—*A. W. Blohm.*

The Financial Limitation in the Protection of Reservoirs. W. W. Ashe. United States Department of Agriculture, Bulletin No. 1430, August, 1926. This bulletin shows that with storage there enters the problem of siltage through erosion of soil, an insidious agency which may cause loss of pondage and consequent reduction in the capacity of reservoirs. The rapidity of erosion and of silting up of reservoirs is affected by different physical and meteorological conditions in the different regions of the United States. Over the greater portion of northern and northwestern United States and in Canada erosion is not the serious problem that it is in parts of the Southeast, and particularly in portions of the Southwest. Attention is called to the high silt burden of certain streams and the rapidity with which storage capacity of reservoirs is reduced, as in the case of the Colorado River (of Texas). The reservoir at Austin on this river lost more than half its capacity within ten years. Many other streams carry a silt burden fully as great as that of the Colorado. On the basins of certain of these streams the surface conditions are such that erosion can be materially reduced. On others the conditions are such that erosion can be only slightly lessened. On these it is a natural condition—the result of surfaces which are naked of protective vegetation on account of irregular rainfall, yet which are subject to excessive erosion of soil, because the limited rainfall is of a heavy and most concentrated type. There

are other regions where protection of the surface is highly efficacious in reducing erosion. It is shown that it is possible to ascertain the rate of silting which is taking place and from this to determine the capital value of the storage capacity, the loss of which might be expected within a given period. It is also possible to determine the extent to which excessive erosion may be checked by artificial means. The author proposes a formula for determining how much money could be economically expended to maintain this capital value, which otherwise would be destroyed by siltage. He points out that in case woods are artificially established for the purpose of securing soil cover and reducing erosion a definite return can be expected from the investment therein, but that power and water companies are justified in making additional expenditures which would be within the capitalized value of the storage capacity which will be preserved. In the Southern Appalachians as well as elsewhere there are alluvial lands which have been injured during floods by gullying or by the deposit of sand and gravel. Where such conditions exist there is an opportunity for the establishment of settling basins. The settling basins proposed would not only result in the elimination of much silt from the stream, but also would bring about the rehabilitation of the devastated lands, which after being built up by deposit of the sediment would again be available for farming. Since this sediment as a rule consists largely of the most fertile soil eroded from the surface of the watershed, areas thus built up would be very fertile. A number of illustrations show the effect of vegetation in the protection of soil from erosion and the surface conditions both in regions subject to erosion and where it is possible to reduce it and in regions where such protection is not effective. Copies of the bulletin can be obtained from the Forest Service, Washington, D. C.—*A. W. Blohm.*

A Treatise on Hydraulics. HECTOR J. HUGHES and ARTHUR T. SAFFORD. Revised and abridged by Safford, 1926. The Macmillan Company, New York, N. Y. In revising this book the authors state that an attempt has been made to decrease the size of the original volume, but at the same time retain most of the material. Some additional data have been added, however, to bring the work up-to-date.

The first chapter is devoted to a history of hydraulics in which brief mention is made of the works of various contributors to this branch of science. Knowledge of hydraulics has gradually increased in the course of centuries until by 1800 it was approaching an exact science. Out of all the work and thought devoted to this subject during the past two thousand years, certain basic principles and formulae have been evolved which, with slight modifications, are the laws still governing the flow of water.

The subjects discussed in the book are hydrostatic pressure, hydraulic flow, the measurement of water in pipes, conduits and open channels, and a brief discussion on water-wheels and pumps. At the end of each chapter, a series of problems based upon the text are listed which make the book of value for classroom use.

The volume is intended primarily as a textbook of hydraulics and no attempt has been made to cover the more complicated problems met with in actual

practice. The authors believe, however, that these can be resolved into their individual parts and solved by the various methods covered in the text.

The material is well arranged and easy to follow. The various mathematical computations are not involved and the solutions follow readily. While the book can be used principally as a textbook of hydraulics, it will be found of considerable value as a reference book to the practising engineer.—*George L. Hall.*

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COMPARATIVE TESTS OF FRICTION LOSSES IN CEMENT LINED AND TAR COATED CAST IRON PIPE[1]

BY MELVIN L. ENGER[2]

The tests were made at the Hydraulic Laboratory of the University of Illinois for the American Cast Iron Pipe Company of Birmingham, Alabama, on 4-inch, 6-inch, and 8-inch pipe furnished by the Company. The purpose of the tests was to determine the loss of head in cement lined and tar coated pipe for various rates of flow.

The pipe lines were laid outward from the Hydraulics Laboratory as shown in figure 1, along a concrete sidewalk and returned to the laboratory with the return pipe vertically above the outgoing line and resting on wooden supports, as shown in figure 2. Twenty lengths of cement lined pipe were laid in the outgoing line and eighteen lengths of tar coated pipe in the return line. The return bend consisted of two 8-inch standard cast-iron quarter bends with suitable reducers in the case of the 4-inch and 6-inch pipe tests. This arrangement is shown in figure 3.

The pipe lines were set up by experienced workmen. The joints were made with lead and jute and there was no leakage from the lines during the tests. The alignment of the different pipe lines was very good.

The average internal diameters of the pipes were determined by

[1] Presented before the Chicago Convention, June 9, 1927.

[2] Professor of Mechanics and Hydraulics, University of Illinois, Urbana, Ill.

averaging the vertical and horizontal inside diameters of each length of pipe about 8 inches from the ends. The average diameters were found to be as follows:

NOMINAL DIAMETER OF PIPE	INTERNAL DIAMETER OF PIPE	
	Cement lined	Tar coated
inches	*inches*	*inches*
4	3.61	3.96
6	5.84	5.88
8	7.86	7.97

Measurement of rate of flow. The flow was measured by an 8-by 3.5-inch Venturi meter shown in figure 4. The meter was cali-

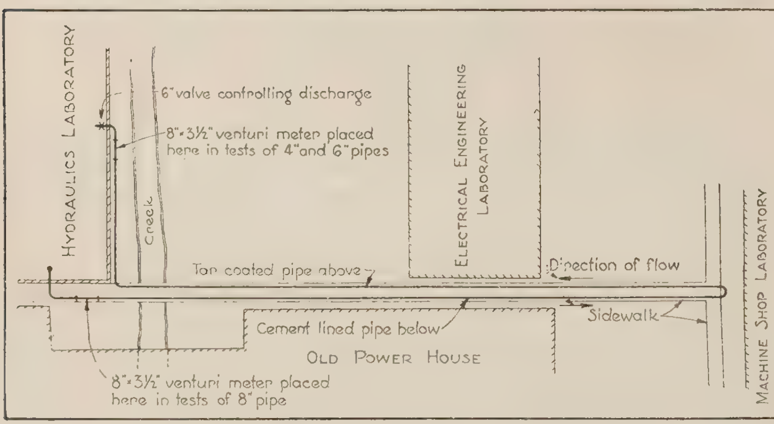

Fig. 1. General Arrangement of Pipe Line

brated in place in the pipe line using a measuring pit to determine the actual rates of discharge. For the higher rates of discharge the difference of pressure at inlet and throat of the meter was measured on a differential gage using mercury; for the lower rates of discharge carbon tetra chloride was used instead of mercury. The Venturi meter was calibrated using each kind of differential gage.

Piezometers. At the beginning and end of the portion of the pipe in which the loss of head was to be measured, four openings, each $\frac{3}{16}$-inch in diameter, were drilled at opposite ends of vertical and

FIG. 2. RELATIVE POSITIONS OF OUTGOING AND RETURN PIPES

FIG. 3. ARRANGEMENT OF RETURN BEND

FIG. 4. LOCATION OF VENTURI METER

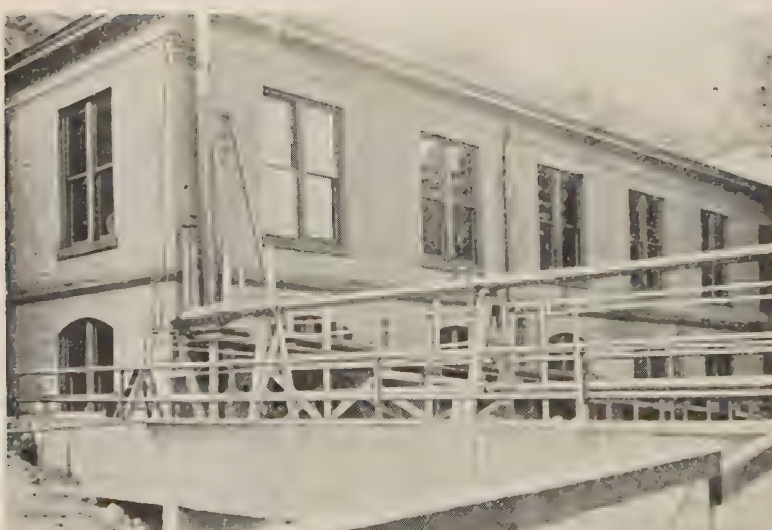

FIG. 5. LOCATION OF LOSS OF HEAD GAGES

horizontal diameters. At these holes $\frac{1}{4}$-inch nipples were held against soft rubber gaskets by means of a clamp. Rubber tubing was used to make the connection between the $\frac{1}{4}$-inch nipples and the $\frac{1}{2}$-inch pipe which transmitted the pressure to the differential gages used in measuring the loss of head. By this arrangement the pressure at the piezometer was the average of the pressure at the four openings, tending to eliminate the effect of local disturbances of flow on the pressure.

The distances over which loss of head was measured were as follows:

SIZE OF PIPE	DISTANCE OVER WHICH LOSS OF LEAD WAS MEASURED	
	Cement lined	Tar coated
inches	*feet*	*feet*
4	193.15	181.04
6	218.50	182.80
8	192.50	193.17

Measurement of loss of head. The loss of head between two piezometer sections in each of the pipe lines was measured by means of differential gages. For the larger losses of head mercury was used in the gages, for the lower losses carbon tetra chloride was used. The mercury gages were about 5 feet high and the carbon tetra chloride gages about 15 feet high. The gages are shown in figure 5.

Water supply. The water was pumped from a pump to a standpipe 4 feet in diameter and 60 feet high. The water was delivered from the standpipe into the experimental pipe line by an independent 12-inch pipe line. The standpipe absorbed pump pulsations which otherwise would have been troublesome in the differential gages.

Method of conducting tests. The rate of discharge through the pipe line was controlled by means of a gate valve at the end. When the flow had become steady after a change of the valve opening the differential gages on the Venturi meter and on the two sections of pipe under test were read simultaneously.

Results of tests. The results of the tests, reduced to losses of head per thousand feet of pipe, with discharges expressed in gallons per minute, are shown plotted to logarithmic scale in figure 6.

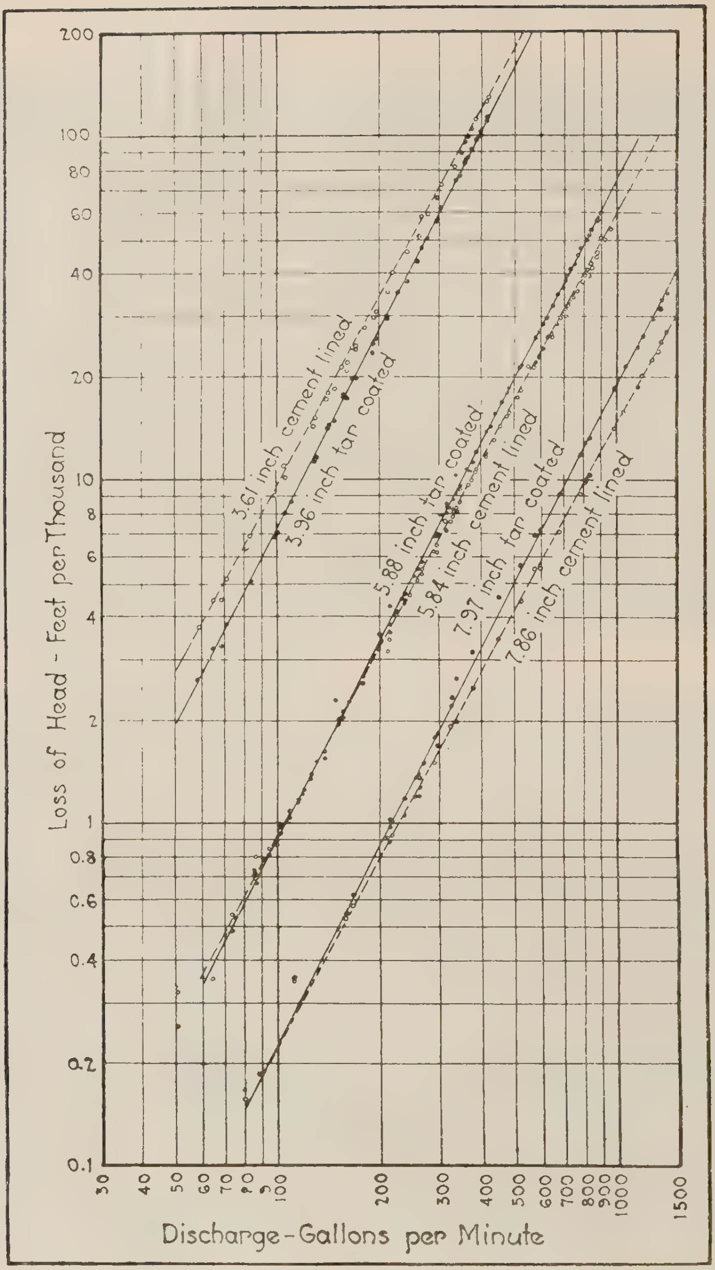

Fig. 6. Results of Comparative Tests on Friction in Cement Lined and Tar Coated Cast Iron Pipe

The following equations, in which h is the loss of head per thousand feet, Q is the rate of discharge in gallons per minute and d is the diameter in inches, were determined from the experiments.

For cement lined pipe

$$h = 1.10 \frac{Q^{1.83}}{d^{4.89}}$$

For tar coated pipe

$$h = 0.94 \frac{Q^{1.94}}{d^{5.00}}$$

The equations should apply quite well to pipe lines as large as 12 inches in diameter and be useful in estimating the friction loss in larger pipes. It should be emphasized that d is the *actual* internal diameter.

Cement lined pipe has a much smoother interior surface than new tar coated cast iron pipe. An uncoated cast iron pipe has a relatively rough interior surface. The tar coating makes the surface smoother, but there are many pinnacles which project above the general surface and cause a decided disturbance in the flow of the water. The cement lining is, or should be, thick enough to cover the pinnacles. The wetted surface can be made very smooth by means of the cement lining. The bond between the pinnacles and the cement no doubt explains the adhesion which permits cutting and calking without serious injury to the cement lining.

The effect of the increased smoothness of the cement lined pipe is to give it a greater carrying capacity for a given loss of head than new tar coated pipe of the *same* diameter, compensating for the reduction in internal diameter due to the cement lining. The tests indicate that, for velocities of flow between 1 and 2 feet per second, a cement lined pipe having an internal diameter 3 per cent less than new tar coated pipe has about the same carrying capacity. At velocities between 9 and 10 feet per second a cement lined pipe having an internal diameter 7 per cent less than new tar coated pipe has about the same carrying capacity.

The relative smoothness of the two linings is shown by the values of "C" in the Hazen and Williams formula from the tests calculated

for a velocity of about 3.14 feet per second. These values are shown below.

KIND OF LINING	INTERNAL DIAMETER	COEFFICIENT C IN HAZEN AND WILLIAMS FORMULA
	inches	
Cement lined pipe	3.61	149
	5.84	151
	7.86	150
Tar coated pipe	3.96	134
	5.88	140
	7.97	132

THE ONE TON LIQUEFIED CHLORINE GAS CONTAINER[1]

By Robert T. Baldwin[2]

Commercially, liquefied chlorine gas became available in 1888 in Germany. Shortly thereafter the Badische Anilin und Soda Fabrik introduced it into the United States. It was shipped in seamless steel cylinders containing about 100 pounds each. These cylinders were fitted with special valves, but were without safety devices. Such packages obviously carried on the tradition of shipping compressed gases in steel cylinders of small capacity, and, moreover, dry liquid chlorine is an inert substance with no appreciable action on iron or steel. However, the imports of German liquid chlorine did not grow for several reasons, viz.: (1) the loaded cylinders were carried as deck loads and were subject to instant jettison in the event of cylinder leaks; (2) there was a heavy American tariff on the steel cylinders, and endless customs red tape in securing drawback of the duty or earmarking of the cylinders; (3) industries requiring chlorine were using bleaching powder and were loath to try a new substance which might not arrive in time for their needs. In 1909 the American liquid chlorine industry started, and the first shipments were made in hundred pound seamless steel cylinders imported from Germany. In the same year the first American Class V tank car holding 30,000 pounds made its appearance. Later seamless steel cylinders of American make holding 150 pounds came into common use.

In 1910 a few steel containers, approximately 30 inches in diameter and 6 feet in length, were devised to hold 2000 pounds of liquid chlorine. This container was a longitudinally welded steel cylinder with welded convex heads and was tested at 500 pounds hydrostatic pressure per square inch. One head had a manhole making internal inspections very easy; and the manhole cover was equipped with two valves, and internal piping of suitable lengths for the eduction of either liquid or gaseous chlorine. These containers had no safety devices and were accepted by the common carriers as box car freight. They were satisfactory both from a safety and technical standpoint.

[1] Presented before the Chicago Convention, June 10, 1927.

[2] Secretary, The Chlorine Institute, Inc., 30 East 42 Street, New York, N. Y.

In 1917 an improved container, substantially the one now in use, was devised for the export shipment of liquid chlorine for chemical warfare gases. This container, like the few of the earlier design, was accepted during the war emergency for transportation by the common carriers in carload and less than carload lots and was satisfactory from a safety and technical standpoint, although not formally approved by either the Bureau of Explosives or the Interstate Commerce Commission, both of which bodies regulate the shipment of compressed gases as well as explosives. In 1920, however, application was made to the Interstate Commerce Commission for regulations permitting the use of this ton chlorine container in carload lots for commercial purposes generally. Effective April 1, 1920, Docket No. 3666, the Interstate Commerce Commission provided for carload shipments of one ton containers in paragraph 1861a, as amended, of the Regulations for the Transportation of Explosives and Other Dangerous Articles by Freight and Express Including Specifications for Shipping Containers, viz.:

> All compressed gases must be shipped in metal cylinders. Provided that chlorine and sulphur dioxide may also be shipped in special tank cars complying with Master Car Builders' Specifications for tank cars for these commodities. Provided further, that chlorine, sulphur dioxide and methyl chloride may be transported in cylinders manufactured and reported in full compliance with B. E. Specification No. 27 effective March 1, 1918, or I. C. C. Specification No. 27 effective April 1, 1920, and loaded on special cradles bolted to cars, if the shipment is loaded by the consignor and to be unloaded by the consignee, under the following conditions: The cars used must be gondola cars with continuous steel center sills preferably all steel underframe, and with wooden floors without drop doors; the plan for construction of the cradles and the methods of bolting to cars as adopted by any shipper must be approved by the Bureau of Explosives; the cylinders must be fitted with safety devices in accordance with paragraph 1862 of these regulations; the marking on the cylinders as required by the specifications must be of such size and so located that it can be easily read by a person on the ground after the cylinders are loaded on the cars, except that a reproduction of the marking on a plate so as to fully comply with this requirement will be permitted.

TON CONTAINER

This one ton chlorine container is now covered by I. C. C. Shipping Container Specification No. 27, Revised January 1, 1923, and Amendments Thereto.

In effect the specification provides for a container eighty inches long overall; thirty inches external diameter; wall thickness 0.375

inch; head thickness 0.75 inch, of open hearth steel containing not more than 0.20 per cent carbon, 0.04 per cent phosphorus and 0.05 per cent sulphur. It is also provided that

All joints and seams shall be made by the forge-lap-weld process and thoroughly hammered or rolled to insure a perfect weld. The heads of the cylinders, except when they form a part of a seamless shell, shall be flanged not less than 4 inches and dished concave under a red heat to a radius equal to the diameter of the shell. They shall be inserted into the shell with flange extending outward and shall have a snug driving fit into the shell. The projecting flanges must be forge-lap-welded to the shell and then crimped inwardly toward the axis line not less than 1 inch on the radius. The welding and crimping of each end to be accomplished in one heat.

The container weighs 1300 pounds; has a water capacity of 1600 pounds and the permitted chlorine loading is 1.25 pounds of liquefied chlorine gas per pound of water, i.e. 2000 pounds. The loading occupies approximately 80 per cent of the container capacity with the liquefied chlorine gas at 68°F. thus allowing for expansion if the temperature is pushed upward.

It is also provided that

Valves and other connections must be made safe from injury during transit by being set into the recessed heads of the cylinder and completely covered by a steel cap. The cap must be made of material at least $\frac{3}{16}$ inch thick; it must not project beyond the flanged ends of the cylinder; and it must be fastened in place by positive fastenings so that it will not come off during transit and so that a blow will not jam it up against the valves or connections.

There are two valves, both in the same head. The loaded containers are always set in the cradles of the car frame in one way, and that way always brings the valve parts at right angles to the length of the container. The two eduction pipes are made of extra heavy $\frac{3}{8}$ inch wrought iron pipe fused into valve bosses made of $1\frac{3}{4}$ inch cold rolled steel shafting and provided with a $\frac{3}{4}$ inch standard pipe thread. These pipes are curved to conform to the shape of the concave head and lie adjacent to the head but do not touch it, and end very close to the sides of the container. Each finished cylinder must be subjected to not less than 500 pounds hydrostatic pressure; must have a regulation identity plate on it; the owner must hold specific approval for each container in interstate commerce; must equip each cylinder with approved fusible plug safety devices; and must supply at his own expense a competent and disinterested inspector who is required to make rigorous tests and certifications of both raw ma-

terials and finished cylinders, for the Bureau of Explosives, and, furthermore, a quinquennial pressure test is required. The safety plugs before referred to are six in number, three in each head and so staggered that three are always below the surface of the liquid contents of the container, and are fusible at 160° to 175°F. At 68°F. temperature the interior pressure in a loaded cylinder is 97.31 pounds per square inch and at 176°F. is 417.48 pounds per square inch, so that there is an ample margin of safety from cylinder ruptures in the event of the undue heating of the cylinder from fire or steam.

As is the case with all containers and their valves, there is a meticulous inspection at the chlorine plant of every ton container; inside and out, before loading, and equally careful outside inspection of each loaded container before shipping.

ONE TON CONTAINER CAR

The aforementioned order of the Interstate Commerce Commission provided for the mounting of fifteen of these one ton containers on a special car frame previously approved by the Bureau of Explosives, the Tank Car Committee of the American Railway Association and the Bureau of Safety of the Interstate Commerce Commission. The first of these cars was put into commerce on January 6, 1922, by Mathieson Alkali Works (Inc.), patentees of special features of the car (U. S. Patents 1,453,475, 1,453,476, and 1,458,588 and others pending). This company has generously made it possible for other chlorine makers to use this type of car. Under a decision of the Interstate Commerce Commission, Docket 2456, effective November 9, 1925, it was ruled that such cars shall be classified and entitled to rates (based on 30,000 pounds maximum loading) prevailing on Class V cars, i.e., tank cars, provided the full complement of cylinders is securely attached to the car underframe whether loaded or empty. This car, known in the chlorine industry as the "multiple unit tank car," is increasingly in use by a number of chlorine manufacturers and is a distinct and valuable contribution to the technic of both producer and consumer of liquefied chlorine gas.

The car admits of three ways of horizontal unloading of liquefied chlorine gas, viz., piping each container separately, piping 15 containers through a car manifold, or the removal of all 15 containers to storage and replacement of 15 empty containers to the car frame.

If the containers be removed and set on end, gas and not liquefied chlorine gas will flow through the valves when discharging.

The ton container makes chlorine storage and use highly flexible and reduces connections by the ratio of 1 for 13 in the case of a consumer who is in the carload class of consumer and cannot well handle Class V cars. Over 100 of these cars are now in use, and they are also coming into service in the shipment of liquid sulphur dioxide.

FREIGHT CHARGES

A 30,000-pound minimum carload of liquefied chlorine gas would require 300 of the 100-pound cylinders or 200 of the 150-pound cylinders. In the first case you pay freight on 27,900 pounds of container as well as on the chlorine, and in the second case on 24,000 pounds of container as well as on the chlorine. On the other hand, the multiple unit tank car pays the same freight rate on exactly 30,000 pounds of chlorine, and no freight on the containers. The car, laden with empty containers, is returned as a tank car without freight charges, thus wiping out heavy return freights on small cylinders. Furthermore, it costs the manufacturer of liquefied chlorine gas more to maintain and load small cylinders than one ton containers, and it follows, therefore, that the consumer receives the benefit of lower cost of chlorine from this cause as well as from the lower freight costs. These savings are appreciable. The first waterworks user (New York City at Ashokan, Kensico, Boiceville and Dunwoodie chlorinating stations) of the ton container recently estimated a net saving of $45.55 per ton of 2000 pounds, basis Ashokan freight rates and consumption. At these four New York City stations a very efficient handling technique has been developed and at least two more New York chlorinating stations are to be equipped to use ton containers. A somewhat more recent addition to the list of water works using the ton container is the plant at Berkeley, California. Los Angeles, California, is arranging to install the ton container.

USES OTHER THAN AT WATER WORKS

Aside from large water works, the ton container has come rapidly into use at paper mills, cotton bleacheries and hypochlorite plants, and recently at a large sewage disposal plant. Obviously the system for unloading and handling at one place is not necessarily the

way to proceed at another place, and accordingly the chlorine manufacturers provide expert service to adjust the ton container to the local situation.

Some very ingenious installations are now in use. For instance, at a large consuming point in a closely populated city district, the multiple unit car can be delivered on a private siding equipped with suitable derailers. An overhead crane with approved tackle removes the ton containers to an underground fireproof concrete storage that can be flooded with water. Alongside and above the car position is a large tank of caustic soda solution, and in the event of any serious escape of gas from containers on cars the caustic soda solution can be released by large valves so as to flood the car and absorb the gas. Such elaborate precautions are not necessary at remote water works and sewage disposal plants, but this installation is a good example of how to adapt the ton container to unusual conditions.

The arrangement of the heads and the frame gear permits the use of an approved simple and sturdy chain hook or straight bar with hooks. Loaded chlorine containers of all kinds should never be handled with makeshift slings, or tilted or dropped on trucks or rolled carelessly on temporary inclined planking and the like. Consumers should consult the chlorine manufacturers and get the benefit of their experience and advice both from a safety and dollars and cents standpoint. The North American chlorine industry has been remarkably free of accidents in handling this noxious gas and every possible safeguard should be had.

At paper mills the ton container is increasingly in use as it fits into their large scale operations easily and greatly increases the flexibility in supply and storage at plants remote from chlorine manufacture.

The ton container is also adaptable to the large scale operation of chlorination of petroleum, natural gas and ores, and to the export of chlorine to the West Indies and to Central and South America as the container can be readily loaded on steamer decks and the returning empties satisfy the requirements for a container complement. In domestic practice it is usual to start the installation by shipping twenty-four loaded ton containers in two gondola cars so as to provide a container complement on discharge of the first multiple unit car. This is the one and only time the ton container figures as a freight cost.

The use of the ton container at sewage disposal plants is an interesting development paralleling the general increase in the use of chlorine gas not only as a sterilizing agent but as an adjunct in practically every kind of sewage disposal now in use in North America. As sewage works are generally remote from densely populated districts and require more chlorine per million gallons than does potable water, the ton container is a vital factor in cost and efficiency of sewage chlorination. It is not suitable for very small operations and probably not for cases where a small amount of chlorine is added to raw sewage well ahead of sewage disposal works to delay septicity and prevent the formation of hydrogen sulphide and stenches, without harm to the subsequent disposal methods. In fair sized sewage plants the ton container has a place and is now in use.

CONCLUSION

Chlorine is unlikely to be made at the point of consumption unless the quantity used is considerable, unless salt and power are cheaply available, and the two inevitable and additional products of the electrolytic decomposition of sodium chloride solutions, namely caustic soda and hydrogen, have nearby uses in a coördinated economic scheme. Under such conditions, chlorine must be cheap. To be cheap it must have suitable points of manufacture, large scale production and a variety of uses. The ton container is therefore a distinct and valuable contribution to the art of handling liquefied chlorine gas, and of great use to both maker and user.

Those contemplating ton container use should carefully figure all costs and avail themselves of the experience and counsel of the chlorine makers.

GROUNDING ELECTRIC CIRCUITS ON PIPES[1]

By Charles F. Meyerherm[2]

The question of grounding electric circuits to water pipes was brought forward for consideration in view of a possible revision of the National Electric Code. This was also taken up by a special Committee in conjunction with the New England Water Works Association. The danger of electrolysis and other hazards incidental to the grounding of electric light circuits to water pipes in accordance with the present requirements of the National Electric Code was given consideration. It was also felt that the position taken by this Association on grounding required revision in view of certain marked changes in the construction of electric and water distribution systems. While no definite action has been taken as yet by these Committees it was felt a report or paper should be prepared advising you of the conditions now existing so as to prepare you for such action as the future may demand.

After considerable correspondence, a meeting of those members of the Research Sub-committee who were interested in the grounding problem was arranged, at which meeting Mr. Blood, Chairman of the Grounding Committee of the National Fire Protection Association, was invited to be present. At this meeting representatives of the American and New England Water Works Association pointed out to Mr. Blood the difficulty which had been experienced with present grounding methods. Employees of water companies, in handling meters and service connections, had suffered severe electrical shocks from currents on these water pipes due to grounded lighting or power circuits. Stray railway currents of large magnitude had been found flowing over the electric light ground wires and specifically installed measures of electrolysis mitigation had been nullified by electric light ground wires. In certain cases where insulating joints had been installed in water service pipes at the main and in the house the connection of electric light ground wires

[1] Presented before the Chicago Convention, June 9, 1927.

[2] President, Albert F. Ganz Company, Inc., New York, N. Y.

to the water service pipe outside of the house insulating joint had resulted in the destruction of these service pipes by stray railway current delivered by the ground wire.

PRESENT AND FUTURE PRACTICE WITH INSULATING JOINTS

To obtain information on the present and future prevalence in water systems of non-metallic pipe and insulating or high-resistance joints in mains and services, a questionnaire was prepared and sent to members of the American and New England Water Works Associations.

This questionnaire covered materials used for existing mains and for services, and approximately how many miles of each material was in service in mains. It also asked what types of joints were used in existing mains and services, and where and how frequently insulating joints were installed in existing mains and services. It asked where the insulating joints in service pipes are located with reference to the building supplied, and what percentage of the existing services contained insulating joints. The final question on existing plant covered the location of meters, what percentage of the meters were located in buildings, and what percentage were located at the curb or outside of buildings. Similar questions were asked regarding new plant and the questionnaire concluded with a request for general recommendations and information regarding trouble experienced with the grounding of electric light and power systems on water pipes.

The American Water Works Association received 108 replies, while the New England Water Works Association received 59. The information obtained from these answers was summarized and tabulated, and on account of its general interest and value is presented herewith as table 1. From table 1 in the section under existing plant, the answers to the questions regarding the kind and amount of various pipe materials in actual service show about 24,500 miles of cast-iron mains, about 1700 miles of galvanized iron, steel or wrought-iron mains, and about 100 miles of cement, wood or other non-metallic pipe. In regard to materials used for existing services the replies show an extremely wide variety, all services however were metallic in nature.

TABLE 1

Digest of information contained in replies to A. W. W. A. and N. E. W. W. A. Questionnaire

	NUMBER OF SYSTEMS	PER CENT OF SYSTEMS
Information on existing plants		
Material in mains:		
All metallic mains	138	90.8
Some non-metallic mains	14	9.2
Total miles of cast iron mains (approximately) 24,500		
Total miles of other ferrous mains 1,700		
Total miles of non-metallic mains 100		
Types of joints:		
In mains:		
All electrically conducting	95	62.5
Some leadite, cement or other high resistance material	56	36.8
Use of special insulating joints:		
In mains at some points	6	3.9
In services at some points	3	2.0
Meter location:		
All meters inside buildings	56	37.6
All meters outside buildings	27	18.1
Some meters inside and some outside buildings	66	44.3
Total meters inside buildings 72.0%		
Total meters outside buildings 28.0%		
Information on new plants		
Material in Mains:		
All metallic mains	152	100
Types of joints:		
In mains:		
All electrically conducting	74	48.7
All leadite, cement or other high resistance material	32	21.0
Some leadite, cement or other high-resistance material	21	13.8
Use of special insulating joints:		
In mains at some points	4	2.6
In services at some points	4	2.6
Grounding and electrolysis troubles		
Reports of trouble from grounding:		
A. C. Circuits	12	7.9
D. C. Circuits	5	3.3
Reports of no trouble from grounding	116	76.3
Reports of existing electrolysis trouble	35	23.0
Reports of past electrolysis trouble, apparently remedied at present	11	7.2

TYPES OF JOINT MATERIAL IN USE

In considering the type of joint material used either from the electrolysis or the grounding standpoint, two main subdivisions are significant, namely, metallic materials whose use results in electrically conductive joints, and non-metallic materials whose use results in joints having a high electrical resistance. According to the answers received approximately 62.5 per cent of the water works systems have used nothing but lead or otherwise electrically conducting joints in existing mains, while 36.8 per cent have used varying amounts of leadite or other similar material having a relatively high electrical resistance. For new work, the use of all lead joints shows a definite decline, because only 48.7 per cent of the replies stated that they expected to use all lead joints, 21.1 per cent stated that they expected to use all leadite or similar high resistance material, and 13.8 per cent expected to use some of each of the above types.

LIMITED USE OF INSULATING JOINTS

The use of actual insulating joints in mains or services appears to be restricted entirely to a few companies who have had considerable experience with stray current electrolysis and its mitigation, and have adopted a definite engineering policy covering electrolysis testing and mitigation. Only 6 companies reported that they had used insulating joints as required in mains, and 3 companies in services. Four companies stated that they expected to use insulating joints in both new mains and new services where electrolysis conditions demanded such protection.

LOCATION OF WATER METERS

From the grounding standpoint, the location of the water meters is important because, in the case of meters located inside of buildings, the ground connection can be attached to the pipes on the street side of the meter, while with meters located outside of the building a removal of the water meter for any cause may nullify the effect of the ground connection and result in hazard to life and property. For this reason copper wire shunts have frequently been required around all water meters where the electric light ground connection of necessity is attached to the piping on the house side of the water meter. The replies to the present questionnaire indi-

cate that 37.6 per cent of the companies have all of their meters located inside of buildings, 18.1 per cent have all of their meters located outside, and 44.3 have their meters located both inside and outside. From the actual figures on the percentage inside and out, as given in the replies to the questionnaire, it would appear that 72 per cent of all of the water meters are located inside of buildings and that 28 per cent are located outside. For new work 54 per cent of the replies stated that they plan to install all meters inside of buildings, 18 per cent stated that they plan to install all meters outside of buildings, and 28 per cent expected to use both methods.

GROUNDING OF CIRCUITS ON WATER PIPES

Regarding the last two items of the questionnaire 76.3 per cent of the replies stated that they had experienced no trouble with the grounding of electrical circuits on water pipes, 7.9 per cent reported trouble from the grounding of alternating-current circuits, 3.3 per cent reported trouble from the grounding of direct-current circuits, and 12.5 per cent expressed no opinion either way. In this connection it is interesting to note that, although not specifically requested to do so in the questionnaire, 23 per cent of the replies included a statement that they were actually having electrolysis trouble at the present time, and 7.2 per cent reported that they had had electrolysis troubles in the past, but that the difficulty had been remedied.

From the foregoing summary of the results of the questionnaire it will be seen that a substantial number (11.2 per cent) of water works operators are actually experiencing trouble from the grounding of electrical circuits on the water pipes, and this would certainly seem to justify reconsideration of the question of grounding electrical circuits on water pipes by the Grounding Committee of the National Electrical Code. So long as no appreciable current flows over the ground connections under normal operation, or for appreciable lengths of time during abnormal operating conditions, there is no reason to prohibit or restrict the use of this method of protection as a general safety measure. Where, however, disadvantages or hazards exist, or the grounding of electrical circuits can be shown to be detrimental to the pipes, such grounding should not be permitted.

The replies to the present grounding questionnaire definitely show the existence of a large amount of pipe laid with high-resistance joints, and the existence of a small amount of non-metallic pipe, and of some instances where insulating joints exist in water mains and

services. In the latter case, the electrolysis problem has forced the water company to spend time, money and effort in testing and applying mitigative measures, to protect their structures and their facilities for supplying a public necessity. It certainly seems unreasonable to assume that in granting permission to ground electric circuits to water pipes for protection in the event of disturbances on the electrical system, the water works operators had surrendered any rights to their own property, or subordinated the use of their structures as water pipes to their use as electrical conductors.

The use of non-metallic joint material is on the increase, while the use of non-metallic pipe and of actual insulating joints will probably continue on new work at about the same rate that it exists in old plants. It is therefore very evident that, from the standpoint of general public safety, a water piping system cannot arbitrarily be assumed to be a continuous metallic conductor. It is true that, generally speaking, the existence of high-resistance joints or possibly insulating joints in water mains will not materially affect the effectiveness of a ground connection as a protection inside the building where such connection is made, but, in the event of substantial current flow over such a water piping system, such joints will cause a marked building up of electrical potential across them and set up a distinct hazard to such pipes and to all persons having to work on them when such potential differences exist. If the potentials are due to momentary disturbances of the electric system they will involve hazard only during relatively short intervals, but if during normal operation substantial current flow occurs over the ground connections, due to disturbances or unbalances of the electric system which are not serious enough to operate the circuit protective equipment, the hazards may prevail for a considerable period, probably until an actual accident occurs.

THE SO-CALLED MULTI-GROUNDED COMMON NEUTRAL SYSTEM

Just recently the attention of your representatives has been called to the so-called multi-grounded common neutral system of electric power distribution which constitutes a serious electrical hazard and an unwarranted use of the piping systems as electrical conductors. The method has been used to some extent in Minneapolis, New Orleans, Omaha, and some other western cities and seems to be coming into vogue in other places. It involves a neutral conductor grid which extends throughout the secondary distribution network; and

to this grid the neutrals of the primary supply circuits are also connected. In each house having electric service the neutral wire is grounded to the water pipes by a direct metallic connection, and at the primary current supply points, the primary transformer neutrals are also grounded to the water pipes.

In this way the water piping system is electrically in parallel with the primary supply system, in addition to the secondary distribution system. In accordance with the law of divided circuits, the water pipes will under the foregoing conditions, normally carry shunting currents whose magnitudes will depend upon the resistance and impedance of the water pipe circuit. Even under normal operating conditions large amounts of alternating current can thus flow over the water pipes and the potential of the pipes at outlying points will be raised to the extent of the voltage drop produced by the current flow. In case of serious unbalance on the primary distribution system extremely large currents may flow over the water pipes and serious fire and life hazards may be set up in houses and also in the street at high resistance or insulating joints, or if lines have to be cut for repair work. These hazards will exist not only during short-time periods required for the functioning of the protective devices but they may exist undiscovered for long periods, because as already explained the shunting currents need not represent serious disturbance of the electric system.

In the multi-grounded common neutral system, the neutral conductor is generally made smaller than the ungrounded conductors, and this definitely shows that the pipes are expected to carry current. As a matter of fact the entire circuit arrangement affords no advantage to the electric light company unless the pipes do carry current under normal operation. This fact, together with the hazards already enumerated, have caused a good many electric distribution engineers to condemn the multi-grounded common neutral system as improper and hazardous.

Metallically connecting the water pipes at numerous places to metallically continuous grid also increases the difficulty and expense of testing, supervising and correcting stray railway current electrolysis conditions. It absolutely nullifies the beneficial effect of any insulating joints which may be installed in the pipe line for electrolytic protection.

In conclusion, your committee would point out that, as far as water works operators are concerned, the present offers just as many

reasons as the past for an active and aggressive policy in connection with electrolysis matters, and in connection with the grounding of electrical distribution systems on pipes. The fact that a comparatively large number of leadite or other high-resistance pipe joints are already in service, and that about 20 per cent of the water works operators are planning to use this type of joint material exclusively, while an additional 14 per cent will use it to a greater or less extent in conjunction with ordinary lead joints, indicates definitely additional serious complications and hazards particularly if such metallically discontinuous pipes are used as electrical conductors for stray electric currents either from power and light or railway systems.

Your Committee would also point out that in using leadite, lead hydrotite, or other non-metallic jointing material in making repairs to existing pipe lines, it is important to know whether or not these pipe lines are carrying appreciable stray current; and, if they are, whether interrupting their electrical continuity with a few isolated non-metallic joints will cause the setting up of dangerous potential differences across such isolated joints. Water works operators should appreciate the fact that the introduction of a few non-metallic joints in an otherwise electrically continuous pipe line which is carrying stray current may set up serious corrosion of the pipe due to the current shunting through earth around the joint.

WATER TREATMENT AND RAILROAD EFFICIENCY[1]

By E. M. Grime[2]

The efficiency of American railways has been increased to a remarkable extent during the past ten or fifteen years. This has not been brought about in any great measure by the construction of additional lines to open up new territory, but by large expenditures to improve existing facilities so as to give better service at less cost. Every feature of railway operation has been scrutinized and changes made wherever a saving could be shown, either in time or operating costs. Not the least of the savings accomplished in this manner has been by the lengthening of locomotive runs. Where it was formerly the custom to operate over a one hundred or one hundred and fifty mile district and then put the locomotive into a house where it was inspected, cleaned, and repaired if necessary, now it is run two hundred, five hundred, or in some cases as far as nine hundred miles at a stretch requiring little more attention than was formerly considered necessary for the shorter runs.

In those cases where the water supply is of very poor quality the accumulation of scale and the concentration of soluble salts may still make it desirable to wash the boiler at the end of a two hundred mile run, but the longer runs are now successfully made in naturally good water territory and also equally well in those districts where, through the skill of the engineer and the chemist, very poor waters have been treated in such a way as to make them practically equal to the best of natural waters. On railways where bad water conditions still exist it has been stated that the correction of this condition promises a larger return on the required capital investment than any other improvement that now remains to be made.

The development of railway water supply facilities has been gradual and naturally followed the increase of traffic. In early days when locomotives were small, a wayside tank holding about seven

[1] Presented before the Boiler Feed Water Studies Session, Chicago Convention, June 8, 1927.

[2] Engineer of Water Service, Northern Pacific Railway, St. Paul, Minn.

thousand gallons was ample and the most primitive methods of pumping answered the purpose, whereas today highly efficient pumping plants, one hundred thousand gallon storage tanks, and water columns delivering a flow of three thousand to five thousand gallons per minute are demanded as a necessity to serve the modern locomotive. Each minute of time that can be saved has a definite value, and on eastern lines of dense traffic, the rather costly open water track pan which permits the filling of tenders without even a stop is justified.

In early days the quality of the water received little attention and almost anything that was wet answered the purpose, but it was not long before certain waters were found to cause serious trouble by foaming and also to fill up the water spaces with a hard scale which it became increasingly difficult to remove. Various substances known as boiler compounds were tried in an effort to overcome this trouble, but as the natural waters in a given district invariably differ in quality, what may be a help with one is not satisfactory for another water and so little was gained by this method of internal boiler water treatment. European railways were the first to investigate methods for improving poor boiler water, but not much was accomplished until in 1841, Clark, of Scotland, successfully used lime to precipitate the carbonates of lime and magnesium and a few years later, Porter, an Englishman, suggested the use of soda ash to decompose the lime and magnesium sulphates. A combination of these two methods for treatment of the water before it entered the boiler was soon worked out. On account of the simplicity of the process and the comparatively low cost of the chemicals involved this method has become the basis for most water softening processes as used on railways.

The desirability of using properly softened water for locomotives became more apparent as railway traffic increased, larger locomotives were put into service and the working conditions became more severe. In aggravated cases locomotive boiler tubes would last only six months and the dropping of crown sheets due to overheating by reason of the insulating effect of heavy scale deposits was not uncommon. Leaky flues would necessitate the attention of boiler makers after every trip, and a combination of these troubles with foaming due to concentrated alkali salts contributed to serious operating difficulties.

Experiments with the use of water softened by the lime-soda pro-

cess indicated that the life of tubes could be considerably increased and boiler repairs materially reduced. This gave quite an impetus to the adoption of methods for treating the water at those locations where it was not possible to find a suitable natural soft water. It is now recognized that to secure efficient results all the water on a given engine district should be softened in order to secure approximately uniform quality. In 1904 the Water Committee of the American Railway Engineering Association reported that 27 railways had been found to have installed water treating plants and in 1905 fifteen others were following the same course and there was no longer any question as to the beneficial results being accomplished. It was found that, as the water was improved, boilermaker forces could be gradually decreased and that the savings to be accomplished were worth while, not only on this account, but also by reason of the shorter time the locomotive was held out of service and the very large improvement in train operation.

SAVINGS DUE TO WATER TREATMENT

Some of the savings accomplished were found difficult to capitalize, but it seemed desirable to arrive at definite data by which to measure the losses due to the use of bad water and the capital expenditure that would be justified to purify a given supply. The Water Service Committee referred to made a careful analysis of these losses in 1914 and came to the conclusion that the damage caused by the accumulation in a locomotive boiler of one pound of scale forming material amounted to 7 cents. Since that time, on account of the increased cost of everything that enters into the calculation, it has been found proper to increase this figure to 13 cents. Stated in other terms each grain of hardnesss in a bad water does a damage of $0.0186 per one thousand gallons of water evaporated. It is realized that a hard sulphate scale will be more injurious than the same thickness of soft carbonate scale, but usually there is a mixture of the two in varying quantities. At the same time there are other elements to be taken into account besides simply the insulating effects due to the scale, and this figure is therefore taken as an average value sufficiently accurate for practical purposes.

That this is very conservative is shown by the fact that the actual losses as determined by the cost of locomotive maintenance in a bad water territory compared with costs in a good water territory show up much higher than may be determined by the thirteen cent figure.

On a leading Eastern railway where the water quality can hardly be considered as being in the very poor class, a careful study of boiler maintenance and fuel costs shows that the annual loss due to bad water on its lines amounts to over $3,000,000 and that in every case the actual loss exceeds what would be indicated by the use of this A. R. E. A. rule. With this as a basis it is not uncommon to find that the savings to be anticipated by reason of boiler feed water treatment are annually twenty-five to fifty per cent of the total amount of the capital expenditure required for construction of water treating facilities. If doubt should still exist as to the correctness of evaluating scale accumulation damage in this manner, on a railway which has both good and bad water territory, a study of the statistics showing the cost of locomotive maintenance per mile may fairly indicate some measure of the damage done by bad water. All other conditions, such as type of locomotive, ruling grades, tonnage, and other operating details being substantially the same, a cost for locomotive maintenance in a certain district regularly exceeding the average cost for this item will show to what extent bad water is interfering with efficient operation. A comparison recently made in this way showed an excess locomotive maintenance cost on a bad water division of $215,000 per annum as compared with an annual loss of $105,000 computed on the 13 cent basis. The improvements suggested as necessary to eliminate this $105,000 are estimated to cost $362,000 and the correction of this condition will therefore show a saving of twenty-nine per cent on the investment.

PITTING AND CORROSION

As a rule the damage done by reason of the accumulation of scale is most apparent in the necessity for washing of boilers at short intervals, of excessive repairs to tubes, flues, and fire boxes, and in fuel losses; but on most Western railways, aside from these difficulties, we have a serious problem in the matter of pitting and corrosion which causes the scrapping of tubes and sheets in but a fraction of what should be their useful life. Some have held that a coating of scale seems to be a protection against corrosion, but in most cases when sulphates of the alkali metal group are present as well as alkali sulphates and the water is thus a good electrolyte, corrosion takes place regardless of the scale. Pits will develop underneath the hardest kind of scale coating and will eventually pierce the metal, causing failure of the tube. Where some kind of internal boiler

water treatment is resorted to, causing partial removal of the scale the pits may be scattered over a wider area and not penetrate the tube quite so quickly. It is now usually conceded that this pitting is due to electrolytic action made possible because the boiler water is a good medium for the passage of minute electric currents between points of differing potential on the surface of the metal. The metal of the tube or shell is dissolved at the anode while hydrogen is plated out at the cathode. Mr. Speller has observed that the smaller the anodic areas with relation to the cathodic, the greater will be the rate of corrosion at the anodic points and therefore the greater tendency to form small holes or pits. This apparently explains the early pitting through of the tube where scale is dense or mostly of the hard sulphate kind as compared with more uniform corrosion, but slower complete penetration, where scale is of the soft carbonate variety.

The Water Service Committee of the American Railway Engineering Association, after conducting extensive tests, arrived at the conclusion that waters which are good electrolytes can be deprived of this quality by adding in the treating process sufficient excess lime and soda to create a sodium hydrate alkalinity. The rule is

$$\frac{\text{Grains sodium sulphate} + \text{grains sodium chloride}}{10} + X$$

equals the grains sodium hydrate necessary to inhibit corrosion. X is a variable covering constituents in the water other than sodium sulphate and sodium chloride. For distilled water X becomes 5, but in the presence of carbonates or hydrates of calcium and magnesium it can probably be disregarded.

In the arid regions of the West many deep well waters are found which contain a large amount of alkali sulphate, but fortunately they frequently also contain sodium carbonate and evidently the latter, under boiler conditions, forms sufficient caustic to act as an inhibitor. It is not unusual to find stationary boilers using such water that have been in service for fifteen to thirty years with practically no corrosion trouble. If any incrustation is seen, it is around hand hole plates where a slight amount of leakage and evaporation has left a rim of caustic soda crystals. A prominent railway is now utilizing these natural deep well alkali sulphate and carbonate waters over an entire engine district, and so far the reports indicate large savings in boiler maintenance costs with no serious foaming troubles and no corrosion.

DEAERATION

It seems evident that corrosion in a locomotive boiler will not continue unless oxygen is present in the water to take up the hydrogen which collects on the cathodic areas and which would otherwise, by its polarizing effect, tend to stop the flow of current. It seems most desirable therefore to eliminate from the feed water as much as possible of the uncombined oxygen. Working on this theory, the open feed water heater which gives the oxygen a chance to escape before the water enters the boiler should materially improve conditions. Experiments to determine this are now in progress on several railways. Where conditions are such that heaters of this type can be used exclusively and kept in proper working order, so far they appear to accomplish definite results in the way of decreasing corrosion. As yet it cannot be said that the experiments are conclusive, but this method of increasing locomotive efficiency will be watched with interest.

EXPERIENCE ON CHICAGO AND ALTON RAILWAY

This polarizing effect of hydrogen which tends to stop the passage of the electric current has been utilized by Mr. Gunderson in some interesting experiments on the Chicago and Alton Railway. By means of two electrodes (anodes) introduced into the boiler below the water line, one at the upper right and the other at the lower left side, extending nearly the full length and perfectly insulated from the boiler shell, a positive charge of electricity amounting to ten amperes for each electrode is taken from the headlight generator and is passed through the water (the electrolyte) into the tubes and boiler shell, thus making every part that might be subject to corrosion cathodic instead of anodic. In addition to this counter electric current, and in order to further prevent the passage of a minute current from one point on the metal to an adjacent point, a so-called secondary cathode is created by adding to the boiler water once every thirty days one pound of sodium arsenate which immediately plates out on the boiler shell and tubes, and by reason of its high discharge potential for hydrogen, assists in holding the hydrogen film which would otherwise be more readily removed by combination with any free oxygen present in the boiler water. Boilers in which this method has been used are almost entirely free from corrosion, whereas others in the same territory and under similar working

conditions have a very brief tube life. For waters where scaling conditions are not serious or where soda ash treatment alone will hold down scale accumulation to the minimum, this counter electrical method promises a large increase in locomotive efficiency.

CHOICE OF TREATMENT METHOD

There are so many factors entering into the treatment of boiler feed water for railway uses that the problem actually becomes somewhat complex and requires careful study in order to select for given conditions the best method of treatment to secure the greatest measure of efficiency. The lime-soda treatment for waters high in the sulphates of lime and magnesium tends to increase the so-called foaming salts and thereby, above certain limits, to add to the difficulties of operation. In his efforts to provide a water free from harmful physical effects and thereby reduce the cost per mile of locomotive maintenance, the water engineer therefore faces the objections of some operating men who fear the slightest foaming trouble which may contribute to traffic delays. We are not certain as to the exact cause of foaming, but it can be shown that a large concentration of sodium salts will not cause foaming, if there is no insoluble or colloidal material present in suspension. Evidently it takes a combination of the above to cause foaming and the density of the dissolved salts as well as the character of the suspended matter also has some bearing. In any event this matter presents difficulties that require constant attention. When treatment is first started and the boilers have not yet become thoroughly freed of scale, in order to have smooth operating conditions, a limited amount of some good anti-foam compound may be found desirable. The basis of these anti-foam compounds is castor oil and experiments have shown that 1 pint of this substance to 5000 gallons of boiler water will hold down a raw water containing as high as 125 grains per gallon of sodium sulphate and 20 grains of insoluble precipitates. Its careful use with a well treated water should therefore solve any foaming troubles. As a rule after water treatment has been in use for a time, if all waters in an operating district are properly softened, the enginemen find they can get along without the compound. The period required to attain this condition will depend on how long it takes to get the boilers thoroughly clean so there is no longer finely divided insoluble material remaining to aggravate foaming. Under these conditions a moderate amount of blowing down combined with the

moderate use of anti-foam compound constitute the ideal operation for greatest efficiency. While the water engineer is interested in a water perfect as far as corrosion and non-scaling qualities are concerned, he cannot lose sight of the fact that the railroad is operated primarily to move traffic and everything else must be secondary to having trains move without delay. Foaming conditions which cannot be controlled with reasonable precautions must therefore be avoided by securing a better water supply even though this may involve considerable expense.

ZEOLITE METHOD OF WATER SOFTENING

A discussion of increased efficiency by reason of boiler feed water treatment would not be complete without mention of the zeolite method of water softening. Zeolite mineral or green sand is a base exchange silicate which has been successfully used for water softening in the industries for a number of years and is now being tried out for railroad use on the Pacific Coast where water conditions are suitable and common salt can be purchased at a favorable price.

The increase in sodium salts by this method makes it desirable to have a raw water low in sodium chloride or sulphate and the less calcium or magnesium bicarbonate, the better. While the lime-soda process removes the calcium and magnesium carbonates, the zeolite simply changes them to sodium carbonates. Zeolite treatment thus increases the soluble solids over ordinary lime-soda treatment, but this is about offset by the excess treatment often required in the lime-soda process in order to secure complete softening and a caustic quality sufficient to inhibit corrosion. While it has not yet been definitely proven, it seems probable that the sodium carbonate produced by the removal of carbonate hardness will, under boiler conditions, change to caustic at a sufficiently rapid rate to inhibit the corrosive tendencies of any sodium sulphate which may be present. For most places in the interior of the country the price of salt is such that for the removal of carbonates lime is a cheaper chemical than salt, while for the removal of sulphates salt is a cheaper chemical than soda ash. For some situations a combination of lime treatment to first remove part of the carbonates and the zeolite to change the sulphates will work out to advantage. After-precipitation in long pipe lines is sometimes a problem with lime-soda softeners and this trouble is not present with zeolite treatment. Zeolite by-products are soluble, making this type of treatment often

advantageous where the disposal of sludge from a lime-soda plant would be a serious problem. The operation of a zeolite plant is simple and it does not require that close technical attention necessary for regulation of a lime-soda plant.

USE OF SODIUM ALUMINATE

One of the principal advantages of the base exchange method is the reduction of hardness to one grain or less, a result difficult to secure by the lime-soda process without using a considerable excess of reagents. It is, therefore, worthy of mention that, where the lime-soda process is in use, by the addition of sodium aluminate the hardness in many cases is being brought down as low as one grain, giving a treated water, which in respect to total solids may be superior to water treated by the zeolite method. Sodium aluminate by an improved process is now being manufactured in the dry form, making it very convenient for handling. Its use is now adding materially to the efficient operation of many water treating plants. When added during the treating process it forms a heavy floc which as it settles has a filtering effect that entangles or drags down the finer particles of precipitate formed by the chemical reactions and gives a perfectly clear water in minimum settling time. During cold weather especially, certain waters, which will not settle out clear for an indefinite period and still remain three or four grains hard, when thoroughly agitated with sodium aluminate solution, will clarify in thirty minutes or less and drop to a hardness between one and two grains. The claim is made that, by the use of this material, the excess treatment with lime and soda, often necessary to bring down the hardness of certain waters, can be avoided to a large extent. This can only be proven by actual tests with each kind of water.

It may be said that a locomotive is only as good as its boiler. As long as steam remains the chief source of power for railroad operation, the condition of the boiler will be a prime factor in operating efficiency. The increasing competition from motor busses and waterways makes the need urgent for more powerful and efficient locomotives. With locomotives approaching what would appear to be their maximum size, the nearest development within reach is along the line of higher steam pressure. Increasing the rate of evaporation increases the rate of concentration of any impurities which may exist in the boiler water, as well as the scale accumulation. The corrosive tendencies then become more active and it is evident that

higher efficiency for the locomotive adds greatly to the necessity for securing perfectly pure water. This is in line with the tendency in stationary plant practice where water approaching zero hardness is now commonly demanded.

Water treatment is essentially an engineering problem. In order to produce the best results and increase the efficiency of the railway, each plant should be carefully considered with reference to its proper location for the best train operation, the availability and quality of the raw water supply as affecting treating costs, and the type of water treating facilities best adapted to satisfy all conditions.

NEW MIAMI, FLORIDA WATER SOFTENING PLANT[1]

By L. R. Howson[2]

The problem of supplying an adequate water supply for Miami, Florida, which changed from a village of approximately 3000 population in 1910 to a city of nearly 150,000 fifteen years later, has been an interesting and difficult one.

The solution has been unique in that the City of Miami, although served by a private water company, has itself deve'oped an entirely new well supply, installed the largest well water softening plant in the country and is delivering the softened water to the private company for distribution.

The water supply has, from the beginning, been drawn from wells which are sunk into the limestone, which at Miami is a spongy appearing formation immediately underlying the sand surface. The original wells were located within close proximity of Biscayne Bay. The supply was hard and under heavy pumpage developed a brackish taste. As the city grew, additional wells were drilled to the west which under heavy draft also yielded a brackish water. The water supply has always been unsatisfactory in appeaarance, for it had a color of approximately 60, and in hardness.

The demands for increased service have been so great that the privately owned water company has been required to make large expenditures for extension of the distribution system and accordingly the betterment of the supply itself was not solved until 1925.

With the increased importance of Miami as a tourist center, the city officials became convinced of the necessity for having a better water supply. Mr. Ernest Cotton, Director of Public Service, made an investigation of the practicability of securing a new water supply at a location further removed from the ocean and the effect of salt water, and resulting from that investigation, the city decided to itself install a new supply near Hialeah, some seven miles west of the city, install there a water softening plant and pumping station and deliver

[1] Presented before the Chicago Convention, June 9, 1927.

[2] Of Alvord, Burdick & Howson, Consulting Engineers, Chicago, Ill.

the water through a long force main to reservoirs near the city. From these reservoirs it was planned to have the water distributed by the Company which would add to its bills a surcharge sufficient to cover the cost of operation and fixed charges on the new plant. This surcharge was to be turned over to the city.

The city voted a bond issue of $750,000 and authorized the construction of the wells and the softening plant.

The city proceeded to drill the wells and during May, 1924, engaged consulting engineers to design the water softening plant. In

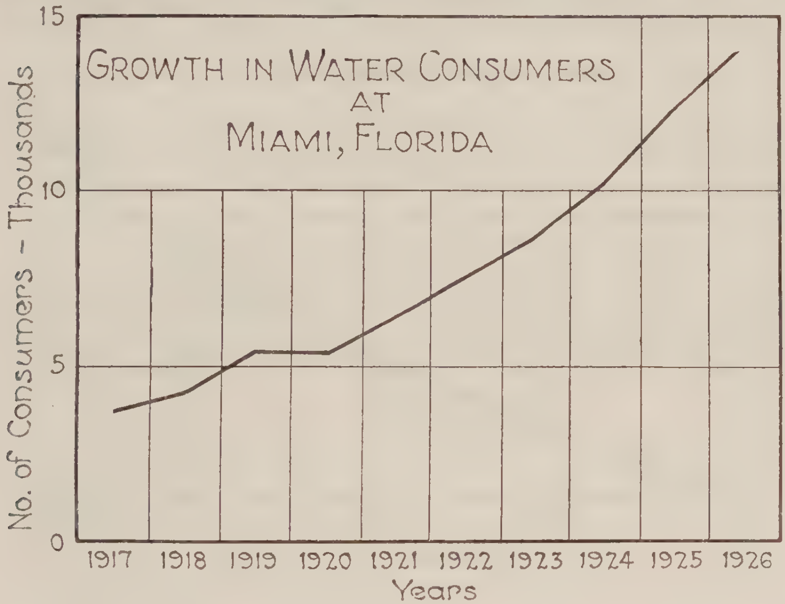

Fig. 1

view of the amount of the bond issue, it was decided to limit the initial construction to a capacity of 10,000,000 gallons per day, even though it was then apparent that practically by the time the plant would be completed, its capacity would be exceeded. It was, however, felt that with a first installation completed, and in successful operation, there would be no difficulty in securing the additional funds necessary to enlarge the plant.

Plans and specifications were rushed for the construction of a 10,000,000 gallon softening plant, and construction was started in

the late summer of 1924. At this time the Florida East Coast Railway had not built its double track line to Miami and the Seaboard Air Line was not built to the East Coast. Embargoes were in effect on many materials and contractors could not bid with any assurance as to costs or time of completion. The city therefore developed its own construction organization under Mr. Cotton and Mr. Jas. H. Cox, Engineer of Division of Water Supply, and proceeded with the construction. Aside from a delay of several weeks when the flood water from Lake Okechobee submerged the site of the work, the construction proceeded rapidly. Softened water was furnished the city from March 5, 1925, and the filters were placed in

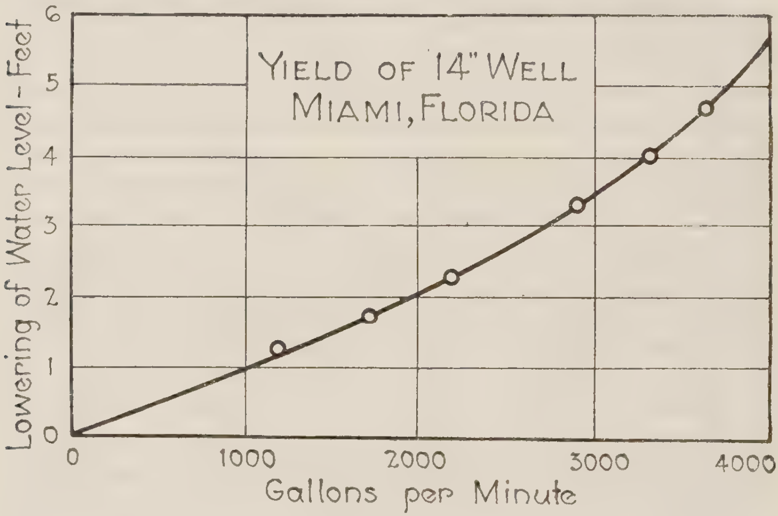

Fig. 2

service on June 5, 1925. In September, 1925, work was started on enlarging the plant to 20,000,000 gallons daily capacity. This was completed and placed in service during June, 1926.

NECESSITY FOR PROVISION FOR FUTURE ENLARGEMENT

With a development so rapid that the number of consumers has doubled approximately every 5 years and the water consumption paralleled this growth, it is manifestly difficult to predict with accuracy future growth. While a study of the past usually furnishes the best guide for the future, even the most optimistic would not

predict an indefinite continuance of the rate of growth which Miami was experiencing in 1924. It was decided, therefore, to build conservatively for the present, but to so lay out all improvements that they might be progressively enlarged without superseding any prior construction. While a plant capacity of 20,000,000 gallons per day would serve the immediate present, it was considered wise to design for an ultimate capacity of not less than 50,000,000 gallons per day. The arrangement of the plant and the layout of conduits and other structures was accordingly made with the idea of utilizing the plant site for an ultimate development of 50,000,000 gallons per day.

THE WELL SUPPLY

The limestone in the vicinity of Hialeah is porous and the wells are accordingly of high yielding capacity. The writer made a test of one of these wells. The well was 14 inches in diameter. The static water level was approximately 5 feet below the ground surface and the pumping was by direct suction. Four thousand gallons per minute were secured with less than a 6-foot drop in the water surface in the well or 700 gallons per minute per foot of lowered water surface.

The water supply from these wells showed approximately the following analysis:

	p. p. m.
Total alkalinity	219
Incrustants	53
Total hardness	272
Calcium	88
Magnesium	12
Free CO_2	25
Apparent color	60

In view of the character of the water which contained only about 50 parts per million of sulphate hardness, it was decided to adopt lime treatment only and reduce the hardness to approximately 90 parts per million, approximately half of which would be remaining carbonate hardness.

FIRST PLANT CONSTRUCTION

The first construction at the softening plant consisted of a chemical house with facilities for unloading and storing of chemicals, mixing tanks of the mechanically agitated type, primary settling basin with

a Dorr clarifier, a secondary plain settling basin, carbonating basin, filters, clear water basin and pumping equipment for the delivery of the water to the City.

Chemical house

The chemical house is a steel frame structure 27 feet by 42 feet in plan and about 60 feet in height. The steel frame work is inclosed by cement stucco on metal lath. The roof is of reinforced concrete slab construction on steel.

The chemicals at present are delivered to the chemical house by trucks which are dumped into a chute leading to the bottom of a bucket elevator of the grain elevator type. This elevator, operating in an inclosed steel shaft, conveys the lime or alum to steel bins which are standard steel tanks with hopper bottoms. The feed of the chemical from these tanks is entirely by gravity. The tanks store approximately 10,000 cubic feet or 200 tons of lime, a two weeks' supply for 15,000,000 gallons daily output.

From the storage tanks the lime passes by gravity through a weigh hopper having a capacity of 2000 pounds thence through a rotary measuring apparatus to a slaker directly underneath and thence to the solution tanks which are of the International revolving paddle type and which are located directly underneath the lime slaker.

It has been found practicable to operate the solution tanks with a very thick lime solution. In each three thousand gallon tank 5000 pounds of lime are dissolved. No difficulty has been experienced at Miami in feeding a solution as thick as this. The lime feed is proportional to the flow through the raw water venturi meter.

The lime dosage is at the rate of $11\frac{1}{2}$ grains per gallon or 1643 pounds per million gallons. Alum in the amount of $1\frac{1}{4}$ grains per gallon is added to facilitate clarification and for color removal. The alum is fed dry.

Chemical storage tanks, scales, slakers, solution tanks, proportional feeds and pumps are all in duplicate. As installed, equipment operates by fill and draw method. The equipment may be changed to continuous slaking and feeding operations and the capacity increased to over 50,000,000 gallons per day.

Mixing tanks

The mixing tanks are of steel on concrete foundations, approximately 30 feet in diameter by 22 feet in height. The water enters

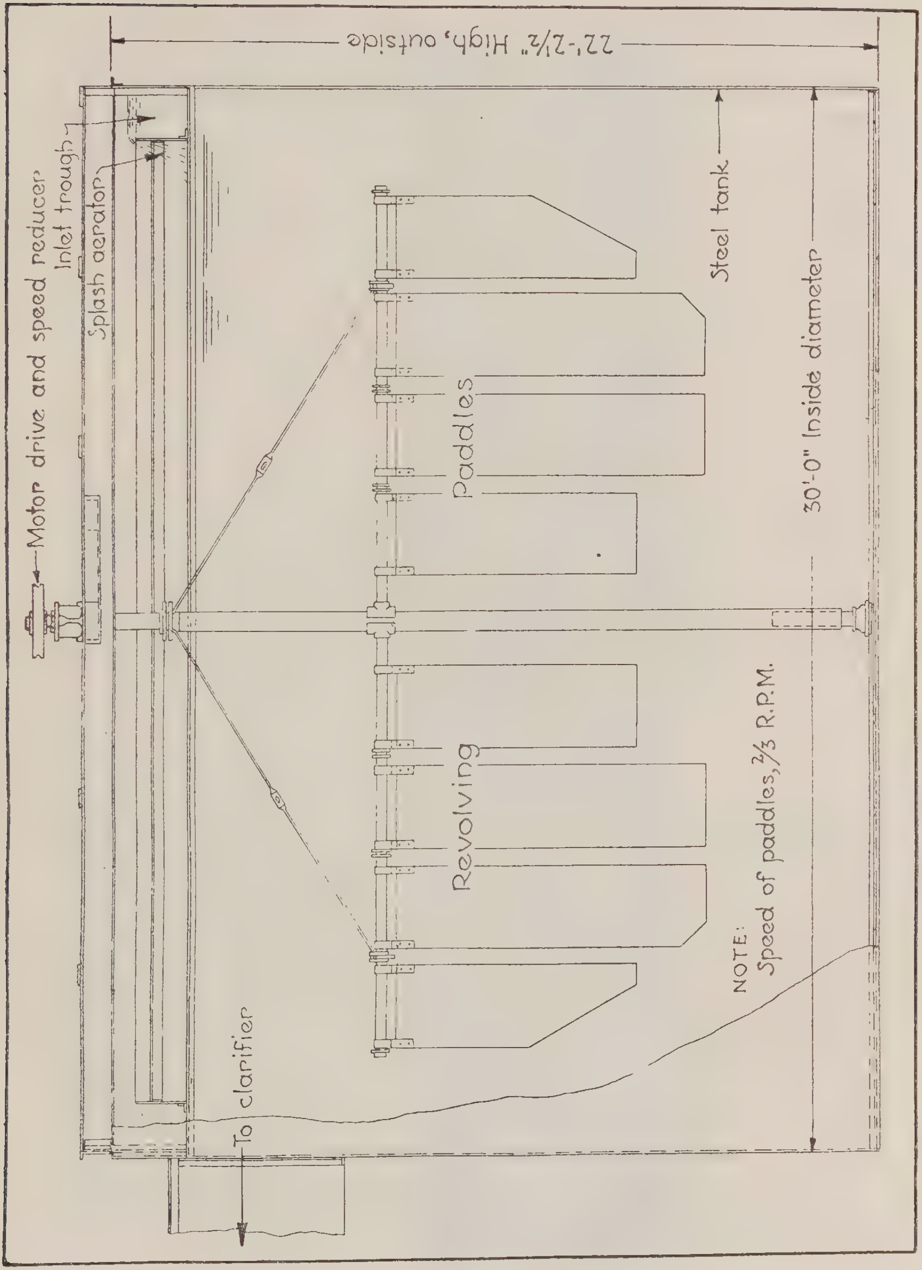

FIG. 3. SECTION THROUGH MIXING TANK

at the bottom of the tank and is conducted through a riser pipe to an annular inlet channel running entirely around the tank. The water in leaving the inlet channel flows over a lip and splash plate arrangement so as to get two falls before reaching the water level in the tank. This is for the removal of CO_2 and this simple arrangement has been very effective in accomplishing that purpose. This aeration has resulted in a saving of approximately 250 pounds of lime per million gallons. The excess pumping head required is but one foot.

Each of these mixing tanks was designed for the treatment of 10,000,000 gallons of water per day. Operation at various rates has demonstrated that this is about the most satisfactory rate of operation. This affords a 20 minute mixing period.

The mixing and agitation is secured by revolving paddles motor driven from a central shaft. The rotative speed is two-thirds r.p.m. which gives a peripheral velocity of about 1 foot per second. In operation it has been found that there has been some sludging in the bottom of the tanks, but this is partly due to sand carried in the water which deposits out readily. It is believed that the paddles as designed would keep the mixing chambers substantially clean, if there were no sand in the water. The paddles at the present time are being lengthened in an effort to keep the water in the bottom of the tank more thoroughly agitated.

Clarifier basin

From the mixing tank the water passes to a Dorr clarifier basin 60 feet square and approximately 16 feet deep, providing one hour detention at a 10,000,000 gallon rate. Experience in operation has shown that when operating at a 10,000,000 gallon rate, practically all of the work of softening, sedimentation and removal of sludge has been accomplished by the clarifier basin. With higher rates and a shorter period of detention in the clarifier basin, more of the unsettled material has been carried over into the settling basin. At a 10,000,000 gallon rate the deposit in the settling tank following the clarifier has been very slight; with the rate increased to 14,000,000 gallons per day, the deposit is approximately 18 inches per month and at 17,000,000 gallons the deposit is at the rate of 24 inches per month. The sludge is removed from the bottom of the Dorr clarifier basin by pumping with a Dorrco pump for a period of about an hour three times daily.

Fig. 4. General View of Miami Plant

The Dorr clarifier basin is baffled at the inlet and the outlet and both inflow and outflow are over wiers. There is no visible short circuiting and the operation has been very satisfactory at all rates even up to double that for which the unit was designed.

Settling tank

Following the clarifier basin there was provided a rectangular settling tank with two hour detention period at a 10,000,000 gallon rate. As before stated, the sludge deposited in this basin has been small in amount varying from a few inches to a maximum of 24 inches per month. It is very light and can easily be removed. It is possible to drain and clean the basin and place it back in service in one day.

The water from the settling tank passes over a wier to the carbonating basin.

Carbonating basin

The carbonating basin is 60 feet square and approximately 16 feet deep. It provides a detention period of one hour for a 10,000,000 gallon rate. The CO_2 instead of being distributed through filtros plates or other type of false bottom, passes through a grillage of small galvanized iron pipes. These pipes are $\frac{3}{4}$ inches in diameter spaced at 2 foot centers drilled at 24 inch center with $\frac{1}{16}$ inch size orifices. Observation of the absorption of the CO_2 gas by the water shows that this type of distribution under a head of 16 feet is very efficient. The carbonization is complete with the period cut to thirty minutes. The CO_2 gas is developed by an ordinary oil burner somewhat similar to the household heating type. The gases are collected and run through a cooler and scrubber. The gas runs about 14 per cent CO_2 and approximately 155 pounds of CO_2 are being used per million gallons of water treated. The cost of the carbonating equipment was less than $3000 and the fuel cost of operating is less than 30 cents per million gallons.

Early in operation of the scrubber some difficulty was experienced due to deterioration of the steel in the bottom of the scrubber. This was corrected by lining the interior of the scrubber with brick and subsequently changing from an asphalt base oil to a paraffin base oil since which no further trouble has been experienced.

Acid tests of the sand in the filters show that the carbonization is effective in preventing sand growth and after deposits.

Filters

From the carbonating basin the water passes directly to filters. The original installation consisted of 4 filters each of 2,500,000 daily capacity when operated at the ordinary water works rating of 2 gallons per square foot per minute. Four additional filters, bringing the capacity to 20,000,000 gallons per day, have since been installed. These filters have nothing unusual in their construction other than that they are of the central gullet type and have a deep gravel layer.

FIG. 5. SUPERSTRUCTURE OF SPANISH DESIGN

By the time the first 4 units were placed in operation, the average pumpage exceeded the rated capacity of the plant and before the next 4 units were completed, the plant was required to operate for as much as a month at a time at an average of 25 per cent above rating or at the rate of $2\frac{1}{2}$ gallons per square foot per minute, and for shorter periods at a much higher rate The filters demonstrated their ability to handle water at high rates without difficulty. It is believed that, in the softening of well waters, whose preliminary

treatment is as satisfactorily performed as at Miami, filters can operate continuously at a rate of $2\frac{1}{2}$ to 3 gallons per square foot per minute without any difficulty, and somewhat higher for short periods if all piping, controllers, etc. are designed with that in view.

Clear well

The clear well has a capacity of approximately 750,000 gallons. It serves substantially as a receiving well and pump section well. It is located under the filters and under the pumps.

Pumping equipment

The pumping equipment consists of 3 pumps having a combined capacity of 20,000 gallons per minute. These pumps are all motor-driven centrifugals operating against 100 feet head. The pumps discharge into a 30 inch main of which a duplicate is now being laid. These mains deliver the water to two 2,500,000 storage tanks, located near the city.

Super-structure

The super-structure is of Spanish design. It is built of stone taken from the excavation for the plant and for the 30 inch discharge main. The stone is a beautiful buff colored limestone which is rather soft when excavated, but becomes very hard on exposure. The surface is of a beautiful rough texture.

There is no roof over the filters proper, but an open arch type of construction with tile roof covers the filter operating floor with similar construction connecting the operating floor with the laboratory, office and pump room.

EFFECT OF HURRICANE

During the hurricane of August, 1926, when the wind reached a velocity in excess of 130 miles per hour, the plant structures were given a severe test and, with a few exceptions, came through in very good shape.

The windows of the pump room are horizontally pivoted with the tops swinging inward. During the storm the fastenings of these windows failed and the wind came into the pump room, lifted some of the concrete roof tiles and carried several slabs as far as the clarifier

basin, some 40 or 50 feet away. These slabs caught the mechanism of the clarifier and stopped its operations.

The roof over the operating floor was anchored by bolts into the stone work. Cracks along the arches show that the wind must have lifted this roof vertically and set it down again in its original location.

It was observed after the storm had passed that the diagonal rods on the wash water tank were sagging. The tank had been painted just prior to the storm. Inspection showed that the turn buckles had apparently unscrewed about three threads as evidenced by the paint lines on the rods. I have yet to find anyone who can account for this phenomenon, but I am informed by Mr. Schmitt, Associate Editor of the *Engineering News-Record*, that a similar observation was made of a tank at Fort Lauderdale.

EFFECT OF SOFTENING UPON WATER USE

Some interesting observations may be drawn from the Miami situation relative to the effect of a better water supply upon water use. A study of the Miami figures shows the following:

1. While the average increase in water pumpage for the four years prior to softening was 14 per cent per year, in the two years after softening the increase was 71 per cent per year.
2. While the average use per consumer for the four years prior to softening was 518 gallons per day, it has averaged 975 gallons per day since the softening plant started operations.
3. The softening plant started operations in June, 1925. In the five years before and subsequent to the introduction of softening, the first 6 months and the last 6 months of the year at Miami show substantially equal uses of water. In 1925 when soft water was available in the last half of the year only, consumption in the last 6 months was 158 per cent of the first 6 months.

While these rather startling figures were undoubtedly due to some extent to the fact that the introduction of soft water occurred simultaneously with the greatest real estate boom at Miami, a study of the figures shows that without a doubt the water supply contributed a large part if not the major part of this growth.

COST

The total cost of the softening plant was $486,961, of which approximately two-thirds was for basin and building construction and one-third for filter and chemical equipment and piping.

With the construction of the second clarifier basin, which will be 110 feet square and for which plans have been prepared, the plant will have a capacity of 30,000,000 gallons per day.

The water supply was investigated and developed by Mr. Ernest Cotton, Director of Public Service, of Miami, Mr. Jas. H. Cox, Engineer of Water Division, organized and executed the construction of the plant. The filter equipment was furnished and installed by the Roberts Filter Company. The lime feeding equipment was furnished by the International Filter Company.

Alvord, Burdick & Howson of Chicago were the engineers, assisted by Mr. Charles P. Hoover on the chemical features and Mr. Victor A. Matteson on the architectural design.

SUPERINTENDENTS' QUESTION BOX SERIES[1]

BOOKS OR CARDS FOR CONSUMERS LEDGERS AND GENERAL PRACTICE IN BILLING

Chairman W. S. Patton: Of 83 replies received to a questionnaire regarding the choice of books or cards for consumers ledgers 33 prefer books, 47 prefer cards or looseleaf and 3 prefer both.

J. E. Gibson (Charleston, S. C.): When I first went to Charleston in 1917, we had bound books for about 5500 consumers. The Department had tried to carry those 5500 accounts in about 6 books; they were great heavy books. We used young ladies for clerks and about all they could do was to carry one of those books. People would come in and want to pay an account that was recorded probably in the sixth book. The clerk had to lift anywhere from the one to five other books to get to it, because whoever used the books last would not put them back on the shelves at the time in uniform order.

I consulted with the Library Bureau people at that time and we decided that we would change to a card ledger system, in which each account was on a card 5 by 8 inches. It carried the information as to the location, the customer, the size of the tap, the size of the main, the size of the meter, the meter number, and when the meter was set, but the principal point on the card after the location of the account or premises, was the column for billing. When we indexed that card it was according to the street number and name; then we made up a corresponding card for the meter reader. We bought a file cabinet that would hold the cards, and it was on rollers, so that in the morning when the office was opened, the first thing the porter did was to roll these account cabinets out in the room where the girls were working. When a consumer came in and wanted to know something about his account, all the girl had to do was simply to pull the drawer open and thumb right to the number of the account. A card index system of accounts carried the number of the account in the ledger file. We found it very satisfactory after some three or

[1] Presented before the Chicago Convention, June 6, 1927.

four months use, when I took a vote of the girls in the department to learn how they felt about the card system versus the old book system. Although at first they had opposed it because they thought there would be some difficulty in using cards and in balancing them at the end of the month.

At first we balanced our accounts once a month, but we are now carrying a control card in each cabinet, so that at the end of each afternoon we close the office to the public at four o'clock and the girls leave at five. At five o'clock they tell me exactly how much money they have collected that day and how many dollars of unpaid bills are outstanding. In other words, we have at the end of each day, a complete balance. We know which water bills have been billed, what money has been paid and what still remains unpaid. In ten years of operation I think we have lost two cards. In one case a young lady was talking to a new minister who came to town. She got out the old account for some reason and he picked it up and slipped it in his pocket and walked off with it. That is the only account we lost. We reproduced that by simply going back to our meter records which carried the meter readings on the card and reproduced the card in its entirety. What became of the other card we have never yet been able to find out. I am inclined to think that it has been placed in the canceled or voided cards that have been filled up and we have not run across it. We have, however, reproduced the card. We never lost any money and we have never had any cases to go into court. I believe that is the one bugaboo about cards or loose leaf ledgers, that the courts do not put much faith in them because a card can be replaced. In a bound book the page cannot be replaced, but I do not see that that need prevent anyone from using the looseleaf or the card system. We prefer the card system. The cards are, as I said, about 5 by 8 and I have them made on rather stiff bond or Bristol board. They stand a surprising amount of wear. They are filed vertically and in billing they are taken out of the box and handled right on the billing machine leaf of the table, so that there is no heavy volume to be handled, or leaves to be thumbed. All of us have been won over to the card system. We certainly would not consider going back to the books.

A MEMBER: Might I ask Mr. Gibson how many hands he employs in the office besides himself.

J. E. GIBSON: In handling the cards there is one lady who makes the bills and a second who posts them. There is a third who has to handle these cards each day because we use a continuous system of reading and billing. The third lady goes back ten days and takes the accounts, bills that are ten days old and makes from those a delinquent notice which she mails at night, so that for handling approximately 10,000 accounts, we have three young ladies. Of course, there are other young ladies receiving cash and attending to the other routine work of signing up new customers and making changes on the books, etc. In the main office we have six in total, one of whom acts as my stenographer and does the general stenographic work for the rest of the office, and our treasurer, who has the general account of the commission; but the three young ladies really handle the consumers' ledger accounts entirely.

CHAIRMAN PATTON: Are there any other questions? I notice in the questionnaire that 33 answered that they preferred books against 47 who preferred cards or loose leaf. I would like to ask everyone who is using books to hold up their right hand. There are fifteen using books. How many are using cards? Thirty. It looks as though we were working into cards.

G. G. WALDROP (Fort Wayne, Ind.): I held up my hand as using a card system. Our system is equivalent to the card system. We use in the billing machine what we call a triplicate stub, as the office stub that is cut off of the bill, after the billing is completed. There is the cashier's stub which is on the paying portion of the bill. When this bill is paid at the cashier's window, she stamps it "paid" and holds it for her records. At the end of the day this stub is compared with the office stub and both are stamped and put in the permanent file. When I took over the office on January 1, 1926, the ledgers were weighing, as our friend stated a moment ago, about 75 pounds each. We found that our ladies could not handle them. We had to replace these ledgers at a cost of $12.00 or $13.00. That is what got me to digging into the proposition and we adopted the short cut method which is proving very satisfactory since the first of this year. I think it is the only system, much more economical and quicker than the others. The unpaid accounts are before you at all times; there is no necessity to leaf through the ledgers, you do not have

to pull them down, and in the course of 90 days we will have our ledgers entirely eliminated and be using the stub system entirely.

S. B. Morris (Pasadena, Cal.): We also use a stub system and have not used the card ledgers or the book ledgers.

R. M. Roper (East Orange, N. J.): I just want to endorse what the last two speakers have said. We in East Orange have about 10,000 accounts. We originally started with the old book system, then some four or five years ago went into the card system. The latter is much more handy for office records than the book system, but both of them had their drawbacks. We investigated all the systems around the metropolitan area of New York and finally adopted one which is used now on a system controlling about a million meters. This system corresponds with that mentioned by the last two speakers, eliminating everything but a reading book, in which we have loose leaves for the original entry of the reading of the meter. From there goes directly to the billing machine. One copy of the bill is our permanent record for the files and it goes into an unpaid file. When the account is paid that is transferred to the paid file and just as Mr. Gibson, with his card system, has a check at the end of each day we have a tabulation sheet which follows in the machine and gives a summary of the total, previous reading, present reading, consumption and financial equivalent, which can give us a balance at the end of every day. We find it is far in advance of either the old book or the card system.

C. M. Crowley (St. Paul, Minn.): We handle about 55,000 meter accounts and during the last four years we have been using cards. Previous to that time we had the loose leaf bound ledgers. We show on the meter reader's book what that meter supplies and the same on the ledger. We find that, where meters stop and we have to pro-rate on accounts, that information is valuable, especially with new accounts, and will give us some data to pro-rate. We charge the ledger clerk with the responsibility of charging that account. He is to determine whether it is to be billed as the meter reader returns it, or held out for a re-reading, or whatever purpose it may be. If he puts it on the ledger, the same reading book goes back to the bill clerk who bills and carries the schedule of the reading, the old and new reading, consumption, water charge, service charge, and

total charge, which is checked by the machine. Then the tally rolls of the ledger clerk and billing clerk are compared which puts the ledgers in balance every night. We find it very economical to divide the city into three districts for the smaller meters, one inch and less. We read one district each month and, much like Mr. Gibson, we keep a continuous process of charging and billing and are able to handle it with one cash window. We have been able to take off our trial balances, generally in about two days and the stubs are always preserved for two years. We keep a control ledger so that when the clerks come to their trial balance at the first of the month they must tie up with the control clerk; then there is no doubt as to the accuracy of our accounts.

Mr. Powell (Griffin, Ga.): Until three years ago we used a loose leaf ledger which was unsatisfactory. We have adopted a card system. We use a billing machine in making our bills and the record on the ledger sheets is made at the same time. We have lighting bills to make, but the same bill carries a customer's lighting, power and water accounts, although the water department and the lighting department are separated. We carry about 2000 water customers and about 2700 lighting and power customers. We only require two girls and, except from the 18th to the 10th, they have pretty much of a loafing job.

Chairman Patton: The next question is, "If books are used, which kind have you found most convenient, books with a page for each consumer, or books with a number of consumers to the page." We received 82 replies; 66 found that one consumer to the page was most convenient; 16 that two or more consumers to a page was most convenient.

Chairman Patton: To the first question 74 replies were received; 58 answered yes and 16 answered no. Do you arrange your meter sheets or your cards the same as the meters? Most of those present seem to prefer to arrange them with the meters. Now the question is, "Do you depend upon an alphabetical index for your ledgers?" We received 79 replies to that question; 31 answered yes; 46 answered no; 2 answered yes and no. It seems to me that an alphabetical index for the ledger is a very nice thing. Where the meter sheets are arranged the same as the writing of the meters, if you have the

house number you can locate your consumer, but it seems to me that an index is a very valuable thing. I will ask Mr. Christy how his are arranged or indexed?

J. F. Christy (Jonesboro, Ark.): They are indexed.

Chairman Patton: Do you use an index?

Mr. Christy: We do in the water department. We have the water, light and sewerage. Everything is in numerical order in the water and also the electrical department.

CONTINUOUS BILLING

CHAIRMAN PATTON: The next question is, "Have you tried continuous billing? Do you prefer it?" 78 replies were received; 35 answered yes; 32 prefer it; 2 were non committal; one does not prefer it. 43 answered no; 40 do not prefer it, 2 were non committal; 1 would prefer it. Continuous billing seems to be the modern trend. Personally I have been opposed to it, but I suppose I shall come to it.

MR. WALDROP: It is the only thing you can do where you have a large number of customers. We have 36,000 in Fort Wayne.

MR. PIERCE (Springdale, Pa): We have a ledger system and a separate sheet for each meter, which are arranged according to the house numbers and street. In Pennsylvania, where this plant is located, the delinquent water bill becomes a lien on the property and we are not interested in the individual. Each sheet corresponds to a similar number in the ledger. When we have to look up a bill we refer to the number. They are all arranged in numerical order.

C. M. CROWLEY: That is the practice in St. Paul. We use a code system, the numbers are consecutive. We split the streets and leave part of that street in one district one month and the rest another month. Our charges are a lien against the property and we do not feel concerned about the arrangement between the landlord and the tenant. They have to settle it themselves.

J. W. CROW (Ponca City, Okla.): In arranging your ledger alphabetically, I do not see how you would have to change your ledger sheets every month, if the tenant moves. If he did move, I would carry mine with the address of the street. If he moved, use the same sheet for the next man who moved in and change his name. It is not alphabetical for the name, but for the location of his meter, the number and name of the street, regardless of who lives there. One tenant moves out and another moves in, you still have his address.

If you carry it alphabetically, you have to change your sheet around every time.

Chairman Patton: I do not believe that there are many plants that could handle it alphabetically. The street number remains the same, but an index arranged alphabetically is a very great convenience.

Are the bills collected by the Treasury Department of the City or by the Water Department?

Chairman Patton: To that we received 83 replies. In 12 cities bills are collected by the Treasury Department; in 47 cities bills are collected by the Water Department; 24 cities are supplied by private water companies.

W. W. Brush (New York, N. Y.): I should like to ask whether anybody here represents a city where the system had been to have the Water Department collect the bills and where that system had been changed to have the City Treasurer, or whatever may be the designation of the financial department, collect the bills. What has been the experience? I ask that because in New York it has been advocated by a good many people at this time that the collection, which is now through the Water Department for current bills, be turned over to our controller or financial officer. Our arrears go to the controller for collection, but our current bills are collected by the Water Department. It would be interesting if anybody has had the experience of shifting from one system to the other, if they would tell us what has been that experience and what is his view of the desirability of such a change.

R. M. Roper: I think I can get at it by reversing Mr. Brush's question. In East Orange all water accounts were collected originally by the City Treasurer's office, even though the Water Department office and the City Treasurer's office were in the same building. We found that there was a great deal of inconvenience caused to the consumers. They would go to the Treasurer's office to pay the bill and some little question would occur to them to ask the Treasurer. He would say immediately, "I will have to refer you to the Water Department," which necessitated a trip to the Water Department

to get the information or some little change in the bill. It would take the consumer's time to go to three places where he should have gone to one. It also piled up the work of the City Treasurer's office, where there was a big line to be handled. About four years ago we changed the system entirely and the water revenues are all collected at the Water Department and turned over and receipted for each day to the City Treasurer. We have had a great many compliments from consumers on the change, because of the convenience to them.

W. W. Brush: Does that change add to the cost for the city, would you think?

R. M. Roper: It takes the equivalent of about half the time of one person as cashier. It does not add to the cost to the city, because it transfers that charge from the City Treasurer's office to the Water Department office, but it is more than made up for in the convenience to the consumers and in eliminating congestion in the Treasurer's office at the time of paying bills.

Phil Carlin (Sioux City, Ia.): At Sioux City until about twenty years ago, the Water Department collected all the bills. About ten years ago the Water Department concluded they'd better have the City Treasurer collect this money. The Water Department sent the bills out, but the Treasurer is on the same floor and close to where our working force is. He collects the money and he can hear all that is being said in regard to any dispute about the bills, etc. We can overhear it and we find that arrangement very handy. We contribute $100.00 a month toward the salary of the City Treasury. It would cost us from $1800 to $2200 a year to collect this money.

Wm. R. Young (Minneapolis, Minn.): For many years the Water Department collected its own bills. It seemed to be a very satisfactory arrangement at that time, but the city made it necessary for all money to be collected by the City Treasurer, and then our collections went through the Treasurer's office. There are approximately 100,000 accounts. The work has been very satisfactory between the Treasurer's collection and our collection. Every afternoon at four o'clock the Treasurer's Department sends to our office all the coupons and a summary of the collection of the day

which runs into many thousands upon certain days. The only objection we can find to this method is that which the gentleman from East Orange pointed out. The Treasurer's office is on the first floor and we are on the second, in a large office building. Many people come in to pay their bills in the office of the Water Department and are referred to the Treasurer's Department. By the time they have gone up to the next floor to pay their bills, they will happen to think that the name may be wrong or the bill may be too large and will be referred back to the Water Department.

Thos. J. Skinker (St. Louis, Mo.): In St. Louis about ten years ago the Water Department collected their bills. The collector now collects them and we have similar trouble to the East Orange company. We have the same complaint about bills which have to be referred back. It is not a very satisfactory arrangement. There is some talk now of changing to the old system, if possible, and letting the Water Department do its own collecting.

Mr. Pierce (Springdale, Pa.): The Treasurer collects the water rents and it seems to work satisfactorily. It eliminates a certain amount of kicks. When consumers came to the water office to pay their bills, they used to think up, or at least we presume they thought up, a complaint about their bills, especially in the summer time when they watered their lawns. By going to the treasurer and paying him, they do not take the trouble to come over and kick to us. Secondly, it saves us a number of duplicate bills. If they forget their bills once and have to walk over to our office, it does not make them feel so very good and they are not so apt to lose the bill the next time it comes. Third, the check which the auditors will be able to obtain is much more satisfactory. We make the bills and charge the treasurer with that amount. He collects them and turns over to us the stubs and the duplicate receipts for the money deposited in the bank, the auditors check our bills against the treasurer and also the canceled checks.

J. F. Christy (Jonesboro, Ark.): We have the best system of all. We collect the money and keep it; we turn nothing over. Jonesboro is a city of about 17,000 population. We are operating under a special act with a commission. We collect all the money and we spend all the money, every bit of it goes right back into the system,

either sewerage, water or lighting system. There is no connection at all with the City of Jonesboro and the water and lighting department. The men are being selected on the basis of property valuation, that is, the property owner gets a vote for every dollar of state and county tax paid, which removes it largely from the political issues which might arise.

We have just completed a new $200,000 power plant. We call on the citizens for no money, issue no bonds against the property whatever. We made a bond issue of $200,000, but only against the power plant. We make all extensions of the water mains with no assessments against the property. We are completing a $30,000 septic tank and spending $15,000 in sewer extensions and there is no charge against the property owner for any extensions or improvements. It is all paid out of the earnings. Everything is handled by the commission elected for this purpose. The sewers are kept up through the earnings of the water and light departments. We have the lowest rate in the state of Arkansas.

ARE BILLS MAILED OR DELIVERED IN PERSON?

CHAIRMAN PATTON: "Are bills mailed or delivered in person, and why?" 77 replies were received. In 50 cities bills are mailed; in 19 cities bills are delivered in person. In 8 cities some are delivered by mail and some in person. Of the cities mailing bills, 19 said it was cheaper to mail them than to deliver them in person; 7 said it was more convenient; 13 that it gave better results and 11 did not give any reason at all for mailing them Of the 19 cities, where the bills are delivered in person, 11 thought it cheaper to deliver the bills in person; 3 thought it more convenient; 3 thought it gave better results and 3 gave no reason.

P. J. HURTGEN (Kenosha, Wis.): We deliver practically all our bills in person. We hold the property owner for the water bill and not the individual and unless the property owner asks to have the bill mailed to him we deliver it in person, for we do not know who is going to pay the bill. Many properties are bought on land contract, and our contract is with the owner and not with the person who holds the land contract. Yet the person who holds the land contract is the person who pays the bill. That is the main reason why we deliver the bills in person, because by doing so we reach the man who actually pays the bill. While on our books we have the name of the owner of the property, he may not be the person who pays the bill.

CHAIRMAN PATTON: I think that is a very important question. I have always thought it was better to mail bills, because a great many people who pay their bills are business and professional men. If you mail the bill it goes directly to his office.

W. W. BRUSH (New York, N. Y.): That is outside of my bureau. My recollection is that in New York we have to send for our bills. That does not refer to meter bills which are mailed, but we have to send for our frontage bills. If we send the postage, they will be sent by the city. The water rents are a lien on the property. Therefore, the question of whether the bills are paid promptly or not is not such

a serious matter in financial returns to the city. It seems to me that, with us, probably mailing would be the better plan, but I am guessing at that because it is something with which I do not personally come in contact.

Geo. G. Waldrop (Fort Wayne, Ind.): We deliver the water bills by hand for 36,000 customers. We absorb this by our meter readers through their idle periods without any additional cost. We consider it more economical.

J. F. Willett (Billings, Mont.): Years ago we used to deliver all our bills with the exception of people receiving two or more bills and they were mailed. We mail all bills now. We find it eliminates a great many complaints where people say they did not receive their bills. The post office department objected to placing bills in the mail boxes. Therefore, when people were not at home, we had to put the bills under the door, or under the screen door, in a place where they might be safe, but the wind would blow them away and a great many people complained that they never received bills. We have greater satisfaction in mailing the bills.

DOES PROPERTY OWNER OR THE TENANT PAY THE WATER BILL?

CHAIRMAN PATTON: In how many cities is the property owner responsible for the bill. We have 30 in municipally owned plants. In how many municipally owned plants are the tenants responsible for the bill? In municipally owned plants apparently 15.

J. F. CHRISTY: I do not believe this question is clear in the minds of these gentlemen. Is it not a fact that, in the payment of these water bills, those of you who held up your hands are mostly metered cities. Do I understand now that the property owners pay these water bills where they are metered or do they require the tenant to pay the water bill? In the period when we used to have so many flat rates, the property owner usually paid the bill, which was a flat rate bill, so much per quarter in advance. The bill was the same every year, depending on what fixtures were in the house. As they began to put in meters, the property owners got away from that. They do not want to stand for the meter bill. They have deducted possibly a dollar or two from the rent and they say, "Now the tenant must pay the water bill." This is good practice.

CHAIRMAN PATTON: How many of the plants here voting are metered?

A MEMBER: Do you mean universally metered?

CHAIRMAN PATTON: Not necessarily, metered or being metered.

J. F. CHRISTY: Seventy-five per cent metered. Do the property owners pay any of the bills that are metered? I would like to ask the next question, how do you find those that pay the meter bills?

STEPHEN H. TAYLOR (New Bedford, Mass): I might say that in New Bedford we only recognize the property owner. We are all metered. Some of our large tenement houses have only one meter

and the owner pays that bill. If he cares to sub-divide it between his tenants, he can do so by private meters, but, as far as the city is concerned, we look only to the owner for the water that goes into his property. We send our bill to the owner. If he passes it on to his tenant and he pays it, that is all right, but the owner of the property is the man we hold responsible for the charge for water in that property.

WM. R. YOUNG: In Minneapolis we hold the property owner responsible for all the water bills, although, if we have no mailing address to which to send the bill, it is mailed to the owner or occupant. Our real estate leases in Minnesota provide, in the majority of cases, that the tenant pay their own water bills. While the property owner is held responsible, it is a matter of mutual agreement between the tenant and the owner as to which one pays it. It is immaterial to us and we do not know who pays it.

MR. HURTGEN: In answer to this question, the state law of Wisconsin provides that any unpaid water bills that are not paid the first of November, are a charge against the property, so that any legislation on this matter must be based on the state law. The state law of Wisconsin provides that any charge whatever, either water bills or repairs on meters are a tax against the property. If those bills are unpaid the first of November, they are to be entered on the tax roll against the property. Our contracts are with the property owner. We have a signed contract with every consumer, that is signed by the owner of the property. The owner of the property owns the meter and is charged with the water bill, if it is not paid by the tenant or the holder of the land contract. That is a state law.

MR. MCDOWELL: I think that is an answer to this question as to whether the bills are mailed or delivered in person. We state that the custom in Charleston is to mail them. We find that that is the more satisfactory method. The contract for water is made with the tenant in Charleston. There is no law in South Carolina that holds the water bill to be a lien against the property.

MR. CARLIN: We have 16,000 consumers in Sioux City, and we are 100 per cent metered. We hold the property owner responsible under our ordinances. I am going to ask a foolish question, while I am on

my feet. How many present allow the turn-off and turn-on men to collect the bad bills, if any?

Chairman Patton: Let me see if I understand your question; you want to know how many permit the turn-off and turn-on men to collect the bills. Do you mean not send any cards at all?

Mr. Carlin: No, no; a bad bill. When they have orders to go out and shut off a certain consumer and that consumer is willing to pay that amount, do they allow these men to collect?

Chairman Patton: You mean delinquent bills?

Mr. Carlin: Regular bills to consumers who have had notices to pay and have not.

Chairman Patton: I would be glad to hear from some one.

Patrick Gear (Holyoke, Mass.): In Massachusetts, we have a state law for a lien on the property, but you do not have to accept it, if you do not want it. The water department can accept it or not. We accepted it, but we did not want it very badly because our Water Commissioner's "yes" or "no" in two minutes is law with them. They could shut off or turn on the water if they were so inclined. They could cut off the water in two minutes, advertise your property and sell it, but, answering Mr. Carlin's question, if we have a bad bill we send a man out to shut it off and if a woman gives him a check and the check is no good, he does not take any other check. There is a law in Massachusetts that, if you issue a bad check you go to jail, so there is no chance of a bad check. We allow them therefore to collect the bill.

Phil Carlin: In a city the size of ours we found in the last two years that a great many double houses, which formerly supplied two families, are being changed into flats, kitchenettes, etc. A great many of the larger houses are changed into duplexes. It is not practical for two meters and we insist on only one meter. We had it out with the real estate board some years ago. They were quite intent upon making the tenant responsible and letting the water department carry on a profit and loss system for their tenants. After

discussing it for some time I wrote thirteen points for them showing why it was impractical. The landlords said the most expensive water they had would be the hot water. One tenant would use it one day and another another day. In the sprinkling season of the year, the sprinkling was done from one service and they could not separate it. There was so many objections to it, that they decided they would have to make it a matter between the landlord and the tenant. Our law makes it a lien against the property. It has been very rigidly enforced. For example, the Department of Education has some blocks where there were tenant houses. We knew nothing of it for some time and they allowed the tenants to remain. The tenants lately vacated the premises and we sent the bills to the Department of Education. They tried to repudiate them, but the City Attorney said they were obliged to pay them for they were a lien against the property.

Mr. Joplin (Princeton): I represent a small, privately owned company. We meter every customer. We also send out delinquent bills with our shut-off man. If he can make the collection well and good. If he does not make the collection, he does not take any promises. It must be the money.

Wm. G. Banks (Newark, N. J.): In Wildwood, N. J., the owner must sign a contract and it is a lien against the property. We serve two other municipalities and the owner must sign for the water where it is not a lien against the property. We issue our bills the first of the year for the minimum charges. If they are not paid, we do not bother with them, but, in the other municipalities, we give them sixty days and at the expiration of that time if they do not pay, we give them a ten day's notice. It must be paid within that time or it is shut off without further notice. We make up an account in the form of districts. The man who makes the turn-off has the amount of the bill plus 1 per cent penalty a month. He must get the money at that time or shut off the water. In Wildwood, proper, where they owe a bill, where it is a lien against the property, we do not bother.

Mr. McEvoy (Dubuque, Ia.): We have 8500 consumers. We do not hold the property owner responsible, except for properties where there are two meters. The tenant pays the water bill in most cases. The owner may, if he wishes to. We have no contact with

the tenant. We require a deposit of $3.00 from each tenant, which is, of course, refunded if they move to some house where they do not use city water. We find that that works very nicely. We read our meters daily and bill daily, that is, we make bills delinquent fifteen days after the bills have been sent out. They receive then a second notice giving them ten days further extension. If the bills are not paid within that time, a shut-off ticket is made out and the water is turned off. They have the right or the privilege to pay the turn-off man with a dollar penalty, before the water is turned on.

J. W. McAmis (Greenville, Tenn.): In reference to whether we deliver bills or mail them, we have a system that is not just like anything I have heard described here. About four years ago, we conducted a little survey in order to find out whether people really wanted a bill or not. We found about 50 per cent did not care whether they had a bill or not, they came to the office anyway. So we do not mail any bills unless a man who wants a bill leaves a request at the office. About 10 per cent of our consumers have a bill mailed out every month and it works out fine. A good many do not want a bill at all, but we do not allow our cut-off man to take any money, unless somebody is sick or in case of death.

Chairman Patton: Do you have meters?

Mr. McAmis: Yes sir. The property owner is responsible for the water bill if he owns the property and lives in it himself. Otherwise we collect a deposit.

Chairman Patton: Mr. McAmis's plan is like ours. We have a $3.00 deposit from the tenant and collect from the tenant. Our loss runs about 1 per cent. I have often wondered if it is not fair to collect from the tenant and make him responsible for the water rather than to hold the landlord. I should like to find out how many municipally owned plants require the money to be paid by the landlord? In other words, how many make the landlord responsible for the bill. Will you please hold up your hand so I can count? Twenty-eight. How many municipally owned plants make the tenant pay the water bill?

A Member: Require or permit?

Chairman Patton: Permit or require. Of course, no one is going to object to the landlord paying the bill. How many will permit the tenant to pay the bill in municipally owned plants only?

A Member: That question works both ways. Although the bill may be held against the property, the tenant may be permitted to pay it.

Chairman Patton: All right, let us change that. Hold up your right hand, if the tenant pays the water bill and the landlord is not held and the bill is not a lien against the property. Twenty. It is pretty evenly divided.

Mr. Pierce: In Pennsylvania the municipally owned plant has a right within three years after the bill comes due, to declare a lien upon the property for it. I do not know of a case where it has been done, for two reasons; in the first place, we can shut off the water and the landlord will pay to get the water turned on. The second reason is that the constable's fee is rather heavy. Here is always a question of whether you are justified in spending five or six dollars to collect a water bill of an equal amount. The tenants can pay the water bill if they want to. We send all our water bills by mail on a government postcard that costs us about a cent and a quarter for the card and the postage. On the face of it, it is addressed to the tenant or owner, and on the back it, is marked for the owner or the tenant. Either may pay it. In the last analysis it is the owner who has to pay the bill.

C. M. Crowley: In St. Paul we have properties standing in the name of an owner whose ownership ceased several years ago. New owners are paying the bill and we do not find more than a quarter of them that will take the trouble to come in and change the name on the records to indicate that they are the present owners. That is the advantage we have in saying that we are dealing with that property. We are interested in this property and want it to pay this bill. We cannot go into research concerning the responsibility of the present tenant, the former tenant or landlord or anything of that kind.

S. B. Morris: You mentioned the fact that you were losers to the extent of one-half of one per cent and you require a $3.00 deposit. We lose about one-quarter of one per cent and require no deposit, except from one or two nationalities from whom we have learned to require deposits.

Chairman Patton: Is the landlord held responsible?

S. B. Morris: No.

Mr. Powell (Griffin, Ga.): We require on ordinary house services, a deposit of $3.00. Anybody can sign a contract who will put up $3.00. If they do not want to put up a cash deposit, they can get the property owner to sign for it. If a man owns his own house, he can sign without putting up a deposit. In every case, however, where the bill is not paid and we have a $3.00 deposit, and the tenant skips out, owing $5.00, say, we hold the landlord for the $2.00 before he can get the water turned on.

Wm. R. Young: In Minneapolis, in 27 years we never lost a dollar on a delinquent water bill, and the first of January, this year, on our delinquent list, we had about $3200. Every one of those bills are against property which is either vacant or the building is wrecked. Before the water can be used on that property again, those bills with penalty will be paid.

HOW ARE METER DEPOSITS HANDLED?

Mr. McEvoy (Dubuque, Ia.): We have a card index system of all consumers. When a tenant comes in and makes a deposit, we simply give him a card as a receipt. Then there is a card made out for him. When he comes in to discontinue the use of water, leave the city or move elsewhere, he brings in his receipt. The card is withdrawn, marked paid, and is put into another file.

Chairman Patton: You do not require the consumer to bring back the original receipt card?

Mr. McEvoy: We do. We tell them that, but it does not make any difference, because we have the record on the deposit card, with that withdrawn, there is nothing against the account. We pay no interest on deposits.

Mr. McDowell (Charleston, S. C.): The tenant pays the water bill in Charleston. The contract is made with him. He is required to make a minimum deposit of $5.00 up to $25.00, depending on the quantity of water formerly used on those premises. We pay 6 per cent interest on the amount of money, if it is allowed to remain with us for a period of over three months. He is given a receipt, which is consecutively numbered in a printed book, and a carbon copy is made of that receipt. When he cancels his contract, he brings back his receipt and he is paid. If he does not have the receipt, a check is mailed to him and we have the check as evidence that he has received the money.

Mr. McEvoy: I wish to correct myself on that card. When he comes in, if he does not have the receipt, or even though he does have the receipt, he signs this card as a receipt which we retain in our files. It is simply withdrawn and put in another file.

Mr. McAmis: We issue a receipt for deposits. We have a vacant place on the ordinary bill, marked "miscellaneous." We put the

amount of the deposit on there and issue a receipt for it. When a man comes back and wants his deposit, we issue a check payable to the person whose name appears on the back as having that deposit with us. In that way we get away from any dispute about who shall collect the deposit; we make it out to the man who gave it to us. If he is dead, his heirs have to put the proper endorsement on the check before they can get the money.

Mr. Bowman (Iowa): It is optional for the tenant to make a deposit for a three month's bill or, if the owner prefers to assume the responsibility, he may. The deposit is entered on the regular ledger card and we have billing cards which are mailed to each customer with a stub or cut-off coupon on it, with the name on the end. The amount of the deposit is entered on the billing card, showing that this is a deposit for a certain service at a certain street and lot number, for the bearer or tenant signing for it, showing a deposit only for that service. The coupon is clipped off, with the same amount on and entered on what we call our regular receiving ledger. In three years we have not had one case of shut-off and no loss, but the amount of the deposit is based not on the dollars and cents for each service, but on a three months billing. For a large customer we require a large deposit, on a domestic consumer, only a small one.

Chairman Patton: What is required if the consumer is dead?

Mr. Bowman: Well, I guess if the consumer is dead someone can come in and sign "John Jones Estate, by So and So."

Chairman Patton: Is any different practice observed in that respect? Do you require an affidavit of any kind if the consumer is dead? I suppose everyone handles it the way we do?

DOES THE CONSUMER SIGN A CONTRACT BEFORE TURNING ON WATER?

W. S. Cramer (Lexington, Ky.): If you require a cash deposit, you have still something in writing.

Chairman Patton: That is all we have with a cash deposit I do not see any need of any contract, but I should like to hear from Mr. Cramer on that question.

W. S. Cramer: We require a deposit only in cash when the landlord refuses to sign. We have a contract that any consumer has to sign before he gets the service. It is optional with the landlord whether he signs or not. The tenant also has the privilege of having any person, who is a water taker, sign that contract. In our city we have in a total population of 50,000, some 14,000 negroes. It is rather a hardship on those people to put up the $5.00 deposit we require where a cash deposit is made. In lieu of that we have a contract signed by both the tenant and the landlord, or by any property owner who is a water taker. The delinquent bill, if any, is added to the bill of the landlord or the guarantor, whoever he may be, and there are very few cash deposits made with us. But we do require a $5.00 deposit and give the usual receipt and a check on its return. As to the question of a person dying, who holds the receipt, the legal representative of that estate can sign the receipt or can countersign the check. We have also quite a number of community hydrants or community taps on property in the poorer negro districts. In a great many cases the landlord pays the bill. We have a system of checking through the books every month and sending the bill as designated by the landlord, whether it comes to him or goes to the property owner. We have a number of apartment houses where the landlord carries the entire bill. For that reason it is practically the rule that the landlord designates whether it shall go to the tenant or come to him. With a proper signing up of the guarantor for the tenant, the tenant may pay the bill.

Chairman Patton: In answer to our questionnaire, "Do you require the consumer to sign a contract?" 83 replies were received; 50 answered "yes" and 33 answered "no." To the question "Do you consider this necessary, if the consumer has put up a cash deposit?" 67 replies were received, 35 answered "yes" and 32 answered "no." If a contract is necessary, let us have it, but if we can get along without a contract, even if we do lose a few dollars once in a while, it seems to me that it is better to do away with the contract.

S. H. Taylor: In New Bedford we do not recognize the tenant. We require the owner to sign the application before we put the service in the property, and, in our service book, to sign an agreement that he will abide by the rules and regulations of the department and pay the bills regularly. We also collect our water bills, $5.00 minimum charge in advance, plus the meter rental. Until the amount of water used exceeds that $5.00, they get no further bill, so that they do not have to make any deposit other than that to get it from the owner.

J. W. Crow: We collect all our money from the tenant and hold the property owner responsible only where he has put up a deposit the same as the tenant. Our minimum is $5.00 and our maximum $100. If the consumer's bill goes higher than the deposit, we raise the deposit and in that way we have no dead heads. We also make them take out the owner's deposit, a receipt which states that they agree to so and so, and this order and receipt is numbered. There is a duplicate. He keeps this receipt and on his return, if he is canceled out, or should lose this receipt, he has to sign a statement that this receipt has been lost, so that none of his folks come back later with the original receipt and take down the deposit. We also keep a record in another book of the number of this receipt, the number of the deposit, his address and the data, so that, if he should have that receipt out twenty years, we can turn back to that book and see the amount he put up, the day he took it out and the number of that deposit. We do not require him to sign a contract any more than to sign his receipt when he takes out his deposit.

Wm. Luscombe (Gary, Ind.): I believe there is an advantage in having a contract signed. Ours is a private plant and it seems to me that the rules and regulations governing consumers are more

easily enforced. It makes it uniform all around for those who are your customers. It puts you on record and serves as the basis of a contract should there be questions of dispute. We require non-property owners to make a deposit. Property owners do not. A deposit sufficient to cover about two months' consumption of water is required. Meters are read monthly.

H. M. Ely (Danville, Ill.): In Illinois the matter of deposit is regulated by the Illinois Commerce Commission. We have nothing to say about it. We require a deposit from non-property owners. Under the Commission's requirement, a deposit is required of twice the monthly billing for a period of six months or a year until they establish their credit. After the credit is established they do not require any further deposit.

CHECK VALVES ON HOT WATER SERVICES

Chairman Patton: The first question is do you require any check valves on your service line, to keep the hot water from coming back through the meter?" Every one who requires a check valve, hold up his hand. Fourteen.

F. C. Jordan: Ask them have they had any blow outs or any trouble like that.

Chairman Patton: Have you had any burst hot water tanks due to the use of check valves. We have had one.

T. J. Skinker: We require the installation of a relief valve when they install a check valve. Where the meter is damaged by hot water, we bill them. There is no law, as far as I know. We just do it and so far we have been getting by with it.

F. C. Jordan: Do you bill the consumer where the meter has been damaged?

Chairman Patton: Do you bill the consumer for any damage to your meter on account of hot water backing through it? How many bill the consumer for damage to meters? Apparently universal.

Wm. Luscombe: Where check valves on services are required, when the release valve fails to function, do you assume the responsibility of damages on that account?

Mr. Sheahan (Memphis, Tenn.): I do not think the water department should, at any time, ask the water consumer to put a check valve on their line from the meter in. I think he is absolutely responsible if he does. Our policy is, if the meter gets hot and gets out of order, to notify the water consumer that he has to fix that meter. If he puts on a check valve it is at his risk and not ours. If we find he does not fix the meter, we will not furnish water, but I do

not think the water department ought to ask any consumer to put on a check valve.

A MEMBER: In Minneapolis we had a case where a suit was brought against us because a consumer put on a check valve and the boiler blew up and killed a man. We notified the city attorney that we did not order any check valve on this place. It was a gravel pit and they had turned on the water and blown up the boiler. The city attorney said that, if we had ordered that checked valve, we would have been responsible for any damage.

UNACCOUNTED FOR WATER

J. W. Crow (Ponca City, Okla.): We get credit for 85 per cent of the water we pump. We have 218 flush tanks and I think I can account for 85 per cent of our water.

J. F. Willett (Billings, Mont.): We have checked as high as 95 per cent. The last two years we ran to 85 per cent and there was a certain amount of water that we estimate is used in flushing sewers from fire hydrants and turned in by the city engineer.

S. H. Taylor: For the past seven or eight years we have accounted for 80 to 90 per cent of the water coming through our meters. That does not take account of the water used for fires and other unmetered duties.

Wm. Luscombe: Our meters register 82 per cent of the water we pump and miscellaneous uses we estimate will bring that up to 90 per cent.

Mr. McDowell (Charleston, S. C.): Our pumping station is located about 9 miles north of the city meters. We have Venturi meters measuring the amount of water leaving the plant and the venturi tube at the city limits measure the amount entering the city. The unaccounted for water between the city limits and the pumping station, where most of the large industries are located, will run about 90 per cent; that in the city about 88 per cent.

W. S. Cramer: There is no such thing as a 100 per cent metered city. Where you are furnishing fire protection, you have always got to make that estimation. On that basis we have unaccounted for water the last year of 11 per cent. The estimate has to be made for the fire department service in any case.

Mr. Winters: We are 100 per cent metered. We have a meter on all sprinkler systems and other connections, a check valve on

every service. For the past two years our actual meter registration that we paid for was 65 per cent of the actual water sent to the city.

Mr. SHEAHAN (Memphis, Tenn.): All water services are metered in Memphis except fire protection. Water meters account for about 70 per cent of the water we pump. We furnish the Fire Department and all charitable organizations, the City Engineering Department and public buildings with free water. This free water in most cases is metered, except the Fire Department, sprinkling system for the City and sewers and water used for the City in general. We find after making a thorough search for the difference we are able to account for all the water except probably 10 or 11 per cent. We have not been able to locate that yet. We think it is in the meter measurements and believe there is a large loss in the larger meters. We put 10 meters under a test for one hour to see how much water went through them before they began to register. Our test showed that 3 per cent of the water that passed through a meter one year in service can be wasted before the meter starts to register, if there should be a leak in the service connection. We find in our test that there have been some cases where meters 10 years in service showed no loss at all; others 10 years old would lose 20 gallons of water before they would commence to register.

We found upon investigation that a meter put in 6 years ago did not stand up as well as the meters that were made in other years. We know no reason for it, unless the material and workmanship at that period was not as good as at other times.

We find that nearly all water meters under-register from $\frac{1}{2}$ to 2 per cent. If a meter bill increases during the month, the property owner will surely be there to tell you, but if the bill is down, there is nothing said. We found in our investigation that about 95 per cent of the meters were low; about 1 per cent were high. In one case we had an over-read of 8 per cent and that meter was 15 years old. By overhauling and putting in new gears, we corrected that.

I would like to ask Mr. Cramer, or any other member, if he ever tried such a test and what results they found.

W. S. CRAMER: We keep an accurate check on our meters, but I would presume that $11\frac{1}{2}$ per cent unaccounted for water was just the general seepage of joint leaks or small leaks in services that do not amount to a great deal individually, but mount up in the total. I

think there will always be unaccounted for losses, even if you are metered 100 per cent.

Mr. Sheahan (Memphis, Tenn.): We have been over this thing carefully and have not allowed as much for underground leaks as we might. I made up my mind that the biggest part of that million gallons that we are short each day is not in leaks. It may be in the measurement. I think we are going to find a good part of that in the large meters. In a little place out east of Memphis they had a 6-inch hydrant and the people were using about fourth-fifths of the amount of the water that passed through that meter. They ordered it cut off. There were 16 houses left on that meter and it never registered. We finally had to take it out and put in a smaller one.

Alexander Potter (New York, N. Y.): I would like to know whether any members have any information as to this unaccounted for water, what percentage is due to under-registration, which I think is very small, what is due to leaky mains and what percentage from out services?

Mr. Winters: In our town they wash the streets with a street washer and count the tanks. I was figuring 10 per cent for dead meters and slippage on meters. We have leaks every month between the curb and the cellar, but there is more or less slippage on all meters. When I said 65 per cent, that was the actual meter registration, the actual billing for the meters. I can account for 65 per cent of my water, figuring our street washer and seepage and dead meters, especially at periods when we do no sprinkling and fall flushing.

USE OF WATER FROM FIRE HYDRANTS BY CONTRACTORS

Mr. Jones (Tulsa, Okla.): I am the engineer for the water Department of Tulsa, Oklahoma. We do not allow anybody to connect on to a hydrant. We send a man there to turn on the water and the contractor has to pay that man four or five dollars a day to stand there and turn the water on or off.

J. F. Christy: That is a problem in every city, large or small. What is always needed is coöperation between the construction department and the city department. When work of that kind is going on with us the water foreman sends a man out to keep in touch daily with that work and look after what is necessary. Relative to connecting to a hydrant, we have an ordinance which protects us in that respect. The hydrant is not supposed to be used for any other purpose than fire; but, if it becomes necessary, they come to our office and get a permit and we send out our own man. We have valves to connect on to the hydrant. We put a valve on, if the water is to be used for any length of time. It is not necessary for the man to stay there all the time. When putting in our sewer systems, there are many places where they are 20 feet deep. We have men go ahead with the ditching machine to remove those lines and reconnect them after the machine passes.

Mr. Jones (Tulsa, Okla.): We have adopted a valve and we open the hydrant in the morning and do not close it until the contractor leaves that night. We operate the valve instead of the hydrant and you will find in the long run that it pays to do that.

ARE CONSUMERS REQUIRED TO COME TO THE OFFICE OR MAY THEY TELEPHONE IN ORDER TO GET THE WATER TURNED ON?

Chairman Patton: Seventy-eight replied; 35 require consumers to call at the office; 13 have made provision to handle by telephone and 30 use both methods.

Mr. Truman (Colorado Springs, Colo.): We will accept telephone calls, but they must be followed up by a written notice to the company to give the consumer water.

P. J. Hurtgen: Our inspector makes a report to the water division that the plumbing is o.k.; then the water can be turned on. When we get the o.k. from the plumber, we turn the water on by a call from the owner. We already have his contract, because he comes in and pays for the meter, or rather when he pays for the service, he has already signed the contract.

Patrick Gear: Does that question refer to new or to old services?

Chairman Patton: This is for old service lines or old taps that have been in a number of years, but the people have been away from home or new tenants have come in and the water has been turned on. This applies to cities where the consumers pay the bill.

Mr. Gear: If it applies to the new ones, no telephone calls will do any good in our place. You must come with the cash to the office. With old ones, the telephone call is all right, if you do not owe any bills.

Alex Milne (Ontario, Can.): It strikes me that these questions reopen the whole problem as to who is going to pay for the water, when the word "consumer" is used. We require the consumer to come to the office and sign for the water. It is not a contract, we do not require a deposit in any case, but he must sign a turn-on order.

In case of a lawsuit, that turn-on order is a legal order in court. If a consumer signs an application for water to be turned on, he assumes liability for the payment, but we insist that the consumer must sign it. That again brings up the whole question as between the tenant and the owner. With us, all water rates become a lien on the property, if not paid, even by the tenant, but with the tenant having signed the application as a turn-on order, which becomes a legal order, we can refuse to give him water in any other house until he pays his water bill, if he defaults. I might say that we have something over 8,000 services. At the present time we have no account which is required to be written off. In the last 15 years we have had no dead accounts.

J. F. Willett (Billings, Mont.): We require only one contract, that is, signing up for your service. We consider that to be continuous for the successor or owner of the property. They are held responsible for obeying the rules and regulations of the water department. We require deposits from all tenants. From property owners, unless they have proved unfaithful to their charge, we do not require them, because we can shut those off and get action on them. We charge $5.00 minimum and an average deposit of two months on other property that runs higher bills.

Mr. Jones (Tulsa, Okla.): The Tulsa department requires a contract which can be signed at any time, but the water will not be turned on until we receive the plumber's certificate that the plumbing is o.k. That contract carries a $3.50 water bill. When that is exhausted, they are billed from then on. If it is the owner of the property he does not have to put up a deposit. If he is a renter he has to put up a $5.00 deposit. We are not taking deposits from anybody, until they move or a new account is opened in their name. The old account stands just as it was before, but, any time you move or change your residence, you must put up a deposit, if you are a renter. If you bring your credentials to the office to show that you are the owner of that property, the water is turned on without a deposit, except that on new contracts we require $3.00 in advance.

Chairman Patton: How many plants charge a turn-on fee for turning the water on after it has been shut off for non-payment? This appears to be unanimous.

DEPRECIATION RESERVES

Eugene F. Dugger (Newport News, Va.): Our Waterworks Plant and System at Newport News, Virginia, was purchased in July of last year for \$3,300,000. The book value of our depreciable assets is a little over \$2,300,000. We are setting up a Reserve Account of about \$45,000 a year which is a little less than 2 per cent. I presume that each waterworks department has definitely determined the life of the items to be depreciated, and has worked up a schedule of depreciation for these items in order to get at a total amount which it charges off annually. This is the way the above amount was arrived at in our city. I feel that my answer to a question of this kind would be of very little help to the waterworks' superintendents in another location, because in different locations the life of certain materials is much longer than others. In other words the amount of \$45,000 which we are charging on a \$3,300,000 investment may not be nearly as large as an amount of \$20,000 on a similar valuation located in some place where soil conditions are vastly different.

Chairman Patton: It has been the practice of a great many plants to take an arbitrary amount, 1 per cent or 2 per cent, and charge that to depreciation and create a reserve with the idea of having the plant appraised at regular intervals and adjust your books in relation to the appraised value of the plant. In small plants I believe it is more easily handled that way than by separating the different parts of the plant and charging depreciation on the different items. Our idea was to find out the usual practice in this respect. I believe I will ask a show of hands. We will find the lowest depreciation that has been customarily charged. Now I doubt if anyone would charge less than 1 per cent depreciation on a plant as a whole. I will ask how many charge 1 per cent or less? Ten. How many charge $1\frac{1}{2}$ per cent? Two. How many charge 2 per cent? Three. Is there anyone charging more than 2 per cent annually, as a whole? One.

J. F. WILLETT: I think that depends on the material of which your plant is constructed. We have three or four different kinds of pipe. Originally our pipe consisted of 25 miles of wood pipe. We took 6 per cent depreciation on the wood pipe and on various materials we take the percentage according to the life of that material. We estimate the life of the material and in our case it will run over 3 per cent.

MR. DUGGER: We charge against the Reserve Account the original cost of the pipe, hydrants, meters, etc., which are being replaced, less salvage value, if any.

JOHN CHAMBERS (Louisville, Ky.): I do not think any of the items just mentioned by this gentleman should properly be charged as depreciation. We carry that as maintenance. If you replace any piece of machinery because it becomes obsolete, that is depreciation reserve. We took out some economizers three years ago and replaced them. That was charged to depreciation. Taps taken out or replaced by a new one are charged to depreciation, but I think the items the gentleman mentioned are maintenance.

MR. DUGGER: They were allowed by the government authorities that came in and put that pump back into its original condition.

J. F. WILLETT: We charge our depreciation against the income account, and such charges as Mr. Dugger mentioned are maintenance charges.

MR. CLAYTON: We charge all maintenances of services on account of paving to our depreciation reserve, and all services which have to be replaced which have not worn out. New services are charged to a separate account, but services put in, in place of old ones not yet worn out, are charged to depreciation.

HOW ARE "BAD DEBTS" HANDLED?

Chairman Patton: I believe you carry them into a bad debt account at the close of the year. The question is do you cancel your bad debts at the close of each quarter or each month, just carrying a memorandum, so as to collect them if you have an opportunity, or do you carry your bad debts into a "bad debt account" and at the close of each year place it into a profit and loss account? Do you cancel them each quarter by entering them on the deduction sheet, or do you carry these into a bad debt account, which, at the close of the year, is closed out through profit and loss?

Mr. Sheahan (Memphis, Tenn.): We set aside $300 every month to cover our bad debts.

Chairman Patton: How does that show up on your monthly report? $300.00 for bad debts each month?

Mr. Sheahan: No, it shows that we set aside that much and at the end of the month, we charge up the bad debts.

Chairman Patton: I think a councilman would say "You haven't any business losing $300 a month; you ought not to lose anything."

Mr. Sheahan: I expect if we had some of the laws I have heard explained here this afternoon, we would not lose anything, but we have to go ahead and charge to the renter or consumer instead of the property owner. If we have any failures or people who cannot pay their bills, we lose it. It amounts to 0.5 per cent a year of our accounts.

Chairman Patton: What per cent of your annual gross revenue is lost by bad debts? How many lost less then 1 per cent? Let me have a show of hands. Sixteen lost less than 0.25 per cent. How many lost as much as 0.5 per cent? Eight. It looks as if we are in the minority.

MR. CROW: If you have a lien against the property how are you going to lose anything? We put up a deposit in my town. I think I lost $9.00 last year and my collections run somewhere around $150.000.

MR. CARLIN: Where you have a council and other city departments, say sewer flushing or something of that kind, and the money is exhausted you have to depend on a future budget. If they do not pay it, you carry it on your books. When we deal with the city departments themselves, we have more difficulty than when we deal with individuals.

C. E. INMAN (Warren, O.): The only case where we lose anything is when a firm goes into bankruptcy. We cannot collect a bankrupt account.

MR. JONES: I do not suppose we lost anything on water bills, but we lose a lot of bills from smaller cities in the neighborhood of Tulsa that call for emergency supplies. After they get the supplies we find that they have not the funds in the department to pay for them. When that year is gone they cannot pay for the water and we have to charge it off.

SEPARATE ACCOUNTS FOR VALVES, HYDRANTS AND MAINS

Mr. Chambers: Hydrants are entirely separate in our accounts. All the valves and appurtenances for water mains are in the mains. Fire hydrants are put in in a peculiar way. In Louisville, the water company has nothing to do with their installation or maintenance; the city charter prevents that. The installation of hydrants is done by the contractor, who has the right to tap the water company's main. All the pipe valves and plugs are charged directly to the line.

Mr. Inman: In Ohio the law reads that all new fire hydrants must be paid for by the Director of Public Safety, and they can issue a bond for the installation of those new hydrants. After the hydrant is once installed, the water department has to take care of it.

Mr. Sheahan: We pay for everything else except fire hydrants.

Mr. Chambers: Why should not everything that goes into a pipe line be charged to the pipe line, except the fire hydrant?

Chairman Patton: I think it should.

Mr. Chambers: I never heard of any other practice; have you?

Chairman Patton: I don't know. At my plant, when I put in a main, I charge the main and everything connected with it to this one extension, but I am beginning to doubt the wisdom of that, because it does not give me an accurate cost per foot of main. I thought I could get a pretty good average cost per foot. It gives it closely enough by taking the hydrants, valves and everything together.

Mr. Chambers: Leave the hydrants out.

Chairman Patton: I have to put in the hydrant lead and a T. We use the same trucks to haul the fire hydrant as the pipe, and I

use the same men in setting the hydrant who cut, fit and lay the pipe. It makes it rather confusing to try to separate a labor and material cost on your hydrant from the labor and material cost on your main.

Mr. Sheahan: Before we lay a main anywhere we have an estimate made of the cost of our 6-inch main laid with valves and connections. They cost about $1.35 per foot complete. In the 6-inch main, the pipe itself costs from 60 cents to 65 cents a foot; with the fittings, the lead, etc., it amounts to about $1.35; the 8-inch pipe $1.60; 10 inch $2.15 and 12 inch about $2.90. We have no rock or hard ground to go through. We put our mains down about four feet. When we dig with a trenching machine it costs about 12 cents a foot less than when done by hand. We charge the city for the connection to the fire hydrant which it furnishes. We get nothing from the city for any water used for fire protection or anything else, and the only thing we get out of it is putting in the hydrant. We put in 10 per cent for overhead in the cost.

Mr. Carlin: We are pretty successful in collecting for hydrants, but I think we collect some bills about which, if we went into court and they asked for a jury trial, we might be doubtful.

Mr. Truman: Is there any privately owned water system represented here? I would like to know how the fire hydrants are handled with the privately owned system. Does the owner of the water system furnish and install these hydrants or does the property owner buy and install the hydrants?

Chairman Patton: The customary practice with privately owned plants is for the company to buy the hydrants and the city to pay a hydrant rental.

Mr. Truman: We do not supply water in an incorporated district. We supply about 3000 users. It is a little extraordinary of course. We have recently made a proposal to our users that, if they buy the hydrants, we would install them free of charge, maintain them and furnish the water free of charge indefinitely, as long as our charter lasts. I was wondering whether that was in line with any other privately owned water system?

Chairman Patton: Are there any plants with mains outside the corporate limits of the city, where the property owners want fire protection?

Mr. Clayton: We furnish both inside and outside equipment and to the city user we make no charge for the fire hydrant and receive only the rental, but when we furnish the communities outside the city limits, they are charged up sometimes against the persons who own the property on which these hydrants are installed and sometimes there is an arrangement made by a group of people. They simply pay the rental and we furnish the hydrant free, so we have no set rule in that respect. We operate under the Public Service Commission rules in Indiana and fire hydrant charges are kept separate, but there is no division made between the main and the valve. They go into one account, but, in general, the fire hydrants are furnished free both inside and outside the corporation. The rental varies from $50 to $60 a year.

Mr. Jones (Tulsa, Okla.): Tulsa is a municipally owned plant, but we furnish water outside the city limits. We permit the property owner outside the city limits to buy the hydrant and we install it. They pay for installing it and we furnish the water and make a contract to reimburse them less the depreciation in the price of the hydrant and the lines when they come into the city. We do not get a hydrant rental.

Mr. Chambers: We do about the same thing in Louisville. We furnish a great deal of water outside the city, but the consumers have to pay for the entire cost of the main and for the cost of the hydrant, if they want it, but not for the water. They pay for everything we do outside the city.

E. W. Agar (Valparaiso, Ind.): We furnish the city hydrants free and they pay $50.00 a year hydrant rental. Outside the city the consumer pays for the service hydrant and pays a water tax. All expense outside the city is paid by the consumer. Inside the city, we furnish the city the hydrants at our cost and the city pays $50.00 a year rental.

Mr. Hurtgen: We have no rental charge for hydrants but we have a per capita charge. Our per capita charge is $1.00 per capita. That amounts to about $75.00 per hydrant. Where we make extensions, we have only one outside the city, we charge up the entire extension at cost and we charge them $100 a year for hydrants and charge them otherwise for their services and meters, 50 per cent in excess of the charge we make to the city. This is of course to discourage extending mains outside the city.

J. F. Willett: What proportion of the distribution system is required to furnish fire protection for a city?

Chairman Patton: In the Manual the figures run about 65 per cent in the average town. I would like to hear some of the members on that.

Mr. McDowell: In one case I analyzed I found that it ran 45 per cent.

Mr. Hurtgen: I might say that that agrees with the situation in Kenosha.

Mr. Willett: In two or three cases I have made estimates of from 35 per cent to 45 per cent. It seems to me an injustice to put in that amount of capital and get no rentals from fire hydrants and let the consumer bear the cost of that fire hydrant rental. Some cities do that. The Public Service Commission of Montana prohibits that if it can. They require hydrant rentals to be paid on all municipally owned plants.

Mr. McDowell: I think the public service commissions are beginning to realize, as they go into the question of rates more thoroughly, that the hydrant rental has not been high enough. I think they recognize that, but inasmuch as some of them, previous to their organization, were so small, they do not like to raise it up to the equitable amount at the present time for fear of adverse criticism. I think though the tendency is for them to allow a higher rate.

A Member: With a corresponding reduction in rates to the consumer?

Mr. McDowell: No, they will only allow a reasonable return. The rate to the consumer should be reduced, but the municipality is not paying to the company an equitable amount for fire protection.

Mr. Jones: Did you say 45 per cent of your plant was fire protection?

Mr. McDowell: Of the distribution system.

Mr. Jones: What class of insurance is your underwriters?

Mr. McDowell: I do not know. I do not have much confidence in these underwriters' associations. They tell you your plant is inadequate, and you tell them you expect to lay a duplicate line because they claim there is a certain amount of risk. You are penalized because of a single line, your pumping station being twelve miles from the city, and you only have a single line. They foresee all kinds of catastrophes whereby that line will be damaged and the town cut out of water in case of a conflagration. You spend $300,000 and duplicate the line, and previous to that you ask them how much benefit those insuring will get if you spend that $300,000 and they invariably answer that your rates are too low now.

IS TYPHOID FEVER A VANISHING DISEASE?

Editorial Comment

Editorial comment in the technical press during the past few years has been justly optimistic in referring to the remarkable reduction in typhoid fever incidence in the United States. A favorite phrase has been that "typhoid fever is now a vanishing disease." It comes with considerable shock, therefore, that in the last twelve months we should have experienced two typhoid fever epidemics which in incidence surpass anything confronting us in the last century. The causes of these two epidemics, separated from each other by the Atlantic Ocean, are of special interest to water works officials and sanitary engineers.

In the fall of 1926, the City of Hanover, Germany, experienced an epidemic of gastro-intestinal disease aggregating 20 to 30 thousand cases in less than three weeks. This was followed during the early part of September by a total of 2500 cases, with 260 deaths, from typhoid fever in approximately 60 days.

A commission of experts, appointed partly by the City of Hanover and partly by the Federal Government, placed the blame, without reasonable doubt, upon a part of the public water supply. This supply was obtained from filter galleries and wells in a gravel soil, relatively unprotected against pollution by surface water. The water supply was untreated in any fashion. During flood waters the supply was heavily contaminated, with the disastrous results noted above.

During the period March 1 to July 16, 1927, the City of Montreal, Canada, suffered a typhoid fever epidemic, in which over 5000 cases occurred with 488 deaths. A special board of the United States Public Health Service reporting on the Montreal typhoid fever situation, stated "From the official record of cases and without consideration of the possible number of additional cases unattended by physicians or not diagnosed and reported, it is evident that since March 1, 1927, Montreal has suffered a severe epidemic of typhoid fever with a case incidence in proportion to population probably unprecedented by any other large city in the world within the present

century." This epidemic beyond reasonable doubt was caused by infection distributed in the output of the milk supply from one of the dairies in the City.

These two situations appear to the writer to demand comment at this time. They carry a moral. They serve as a warning of our human frailities in control of our water and food supplies. Epidemics of enteric fever in enlightened countries do not "vanish." *They are merely held in abeyance by the most rigid control of the source, treatment and distribution of these supplies.* This control is becoming increasingly difficult with the enormously increasing pollution of practically all areas and streams by human wastes. These terrible afflictions, occurring immediately upon the gratifying announcement of the low typhoid fever death rates, may have a salutary effect. They illustrate once more that "the ghosts of environmental diseases may have been safely laid in literature, but certainly not in fact." These events throw down the gauntlet to the members of the American Water Works Association. It is to them in a large measure that the public must look to hold in check that "vanishing disease," which every now and then escapes its leash.

ABEL WOLMAN.[1]

[1] Editor, JOURNAL OF THE AMERICAN WATER WORKS ASSOCIATION; Chief Engineer, Maryland Department of Health.

SOCIETY AFFAIRS

THE ANNUAL CONVENTION

The forty-seventh annual convention of the American Water Works Association was held at the Hotel Sherman, Chicago, Illinois, on June 6 to 11, 1927, with a total of over 1600 members and guests present. These were divided as follows: Active Members, 771; Associate Members, 300; Guests, 538.

Afternoon Session, June 6. The first conference of the convention took place on Monday afternoon, when a Superintendents' Round Table Discussion was held, under the auspices of the Plant Management and Operation Division, with W. S. Patton in the chair. The subject under discussion was "Water Works Accounting,"[1] based on a series of questions prepared for consideration.

Meetings of the Standardization Council, George W. Fuller, chairman, and of Committee No. 1, Standard Methods of Water Analysis, were also held during the afternoon.

A musicale and reception for the ladies was held under the auspices of the local committee in the afternoon.

An informal evening reception and dance in the grand ball room, under the auspices of the Water Works Manufacturers' Association, closed the day.

Morning Session, June 7. The convention was officially opened on Tuesday morning at 9:30, with the president, Allan W. Cuddeback, in the chair. In his opening address, Mr. Cuddeback said he believed the convention would be the largest and best the association has ever held. He called attention to the great growth of the association in the past few years, it now having 2 divisions, 15 sections and 2 affiliated societies. He referred to the great work accomplished through the Standardization Council as a guiding authority, both to the body itself and to its committees.

One of the most important actions taken was the formation of a committee to gather material for revision of the Manual of Water Works Practice, preparatory to the issuance of a second edition.

[1] This Journal, page 455.

In closing he urged the members to realize their individual responsibility and aid in this revision.

Secretary Beekman C. Little then read the list of new officers elected as follows:

President: James E. Gibson.

Vice-President: William W. Brush.

Treasurer: George C. Gensheimer.

Trustees: District No. 2: Seth M. VanLoan. District No. 8: L. R. Howson. District No 9: George W. Pracy.

The reports of officers followed, including that of the secretary and the treasurer, the electrolysis fund, and the budget committee. All of these were accepted and ordered filed.

The Diven Memorial Medal, given to the member who has done most for the association during the current year, was awarded, in an appropriate speech, by Mr. Milne, chairman of the committee on award, to Arthur E. Gorman, chief sanitary engineer, of the Chicago Department of Public Works, and secretary of the local convention committees.

The medal was presented to Mr. Gorman by President Cuddeback. The recipient said in accepting it that he considered it not as a personal award, but as a recognition of the work of the committees of the convention. He referred to the splendid coöperation he had received from both the American Water Works and the Water Works Manufacturers' Associations.

A handsome gavel was presented to the retiring president by Mrs. Charlotte Diven, widow of former Secretary Diven, in memory of him.

The report of the Standardization Council was given verbally by its chairman, George W. Fuller. He announced two new committees, one on standpipes and water towers, J. E. Gibson, chairman, and the other on steel pipe lines, J. Waldo Smith, chairman.

Mr. Fuller described at some length the work in connection with the international committee of the League of Nations on standard methods of water analysis, referring to the coöperation between American and foreign water works men.

He spoke of the work accomplished by committee No. 19, on boiler feed studies, under the able chairmanship of Sheppard T. Powell.

Mr. Fuller pointed out the great opportunities for service which were in the grasp of the association, along the line of developing public opinion as to the work of the men who regulate the activities of

public utilities, especially the water works. The association can do much also in developing the better class of men at the heads of municipal plants and by increasing more satisfactory relations between such plants and their consumers. He hoped that the time would soon come when not only the number of sections of the association would be increased, but also that regional meetings of several sections would be held.

He announced that the abstracts of articles in the technical journals had been approved and would be continued. In referring to the Manual of Water Works Practice he said that a second printing had been accomplished last October, and that 571 of the second 1500 had already been sold. A new committee on the revision of the Manual had been formed. A second edition of the Manual would depend entirely upon the interest and assistance all of the members of the association gave this committee.

The only paper of this session was read by W. D. Collins,[2] on "Quality of Water and Industrial Development;" discussion by Bartow, Brush, McDonnell and others.

Afternoon Session, June 7. President Cuddeback in the chair. The following papers were read: "The Underwriters' Laboratories and Water Works Equipment," by Dana Pierce. "Restoration of Water Service in Miami Following the Hurricane," by H. H. Hyman. "The Chicago Avenue Tunnel Construction Methods," by John S. Dean. "Chlorination Control in Chicago," by A. E. Gorman. "The New Water Supply of Amarillo, Tex.," by Wynkopp Kiersted, Jr. Mr. Gorman's paper was discussed by Bartow, Brush, Howard and Gorman, and Mr. Kiersted's by Alexander Potter.

Evening Session, June 7. The convention was welcomed by Richard W. Wolfe, commissioner of public works of Chicago, in the absence of Mayor Thompson. The only paper was on "A Program for Improvement of Water Service in Chicago," by Myron B. Reynolds.[3]

At 11:30 a.m., June 7, the ladies were taken on a trip to Marshall Field Store, with style show and luncheon, compliments of the local committee. In the evening there was a card party, compliments of the Water Works Manufacturers' Association. This was in charge of Mrs. W. C. Sherwood and committee.

Morning Session, June 8. President Cuddeback announced that

[2] Journal, August, 1927, page 259.

[3] Journal, August, 1927, page 163.

the following officers had been elected for the plant management and operation division; President, W. E. MacDonald; vice-president, Thomas L. Amiss; secretary, R. B. Simms; directors, Thomas R. Henderson and Samuel B. Morris.

Four papers were read at this session, as follows: "Distribution System of the Chicago Water Works," by J. B. Eddy. "Legal Decisions Affecting the Financing of Water Utilities," by Cecil F. Elmes; discussed by J. W. Alvord and E. W. Bemis. "Public Relations," by Daniel T. Pierce,[4] read by C. A. Emerson, Jr. The final paper was by F. B. Leopold, on "Duplex Filter Bottoms." The paper on "Public Relations" was discussed by Denman, Henby, Hopkins, Leisen and others.

Afternoon Session, June 8. The afternoon session was short, on account of a boat ride scheduled at four o'clock. The first paper was by H. F. Wiedeman, on "The New Water Works Plant at Spartanburg, S. C."

The second paper was by D. C. Grobbel, on the "Application of Machines for Water Consumers' Accounting Problems." This paper was discussed by D. E. Werner. The final paper of the session was by William W. Brush, on "Compensation of the Executive and Technical Forces Employed in Water Works and Other Utilities."

As Mr. Brush was about to begin the reading of his paper, President Cuddeback announced the sudden death in the hotel, of Charles R. Wood, of R. D. Wood & Co., and that, in consequence, the smoker scheduled for that evening, would not be held.

The nominating committee reported the following names of candidates to be voted upon for offices during 1928-1929: For president, William W. Brush; for vice-president, Jack J. Hinman Jr.; for trustees: District No. 1, C. D. Brown; District No. 2 Stephen S. Taylor; District No. 6, John Chambers.

At 4 p.m., the entire convention was taken on board a lake steamer and given a two-hour sail on Lake Michigan, returning via the Municipal Pier at about 6 p.m. This was by courtesy of the Chicago local committee.

In the evening there was a theatre party for the ladies, compliments of the Water Works Manufacturers' Association, and under the charge of T. R. Kendall.

[4] Journal, August, 1927, page 262.

Morning Session, June 9. The morning session of Thursday was taken up by a symposium on Well Water Recessions. Jack J. Hinman, Jr., was in the chair. The first paper was a general review of the subject, treated by M. M. Leighton, and discussed by G. C Habermeyer.

At the conclusion of the discussion at the Morning Session by G. C. Habermeyer, in connection with the "Symposium on Well Water Recessions," President Cuddeback took the chair and a series of resolutions were introduced as follows, all of them being adopted as read:

RESOLUTION ON THE DEATH OF CHARLES R. WOOD

WHEREAS, the late Charles R. Wood departed this life the 8th day of June, 1927, at the Hotel Sherman, in the City of Chicago, and during the 47th Annual Convention of the American Water Works Association in which he was taking an active interest, and

WHEREAS, the deceased has for many years been a very active and stimulating influence in the councils of our Association, having given of his best to the advancement of its interests, and

WHEREAS, we, members of this Association will miss his counsel and advice in our circle, and his friendship and good fellowship in our social relations, therefore be it

Resolved that we, the members of the American Water Works Association, in session at our annual meeting in the Hotel Sherman, Chicago, Ill., June 9th, 1927, regret his untimely demise and hereby register this expression of our loss, and it is

Ordered that this Resolution be spread upon the minutes of this meeting, and that a copy of these Resolutions be engrossed and forwarded to our deceased member's family.

RESOLUTION ON WATER WASTE POLICY

WHEREAS, we, the members of the American Water Works Association are in convention assembled at Chicago considering matters relating to the water supply problems of municipalities; and

WHEREAS, it is our purpose to aid in serving the public, not alone in the supply of water, but in the conservation and treatment of water; and

WHEREAS, pure air and water are paramount necessities of human like; and

WHEREAS, a supply of pure water is a necessity to every city; and

WHEREAS, the use of water in reasonable amounts is necessary for the conservation of the natural resources of the country; and

WHEREAS, unreasonable use of water by wilful or ignorant waste is a matter which it has been the function of the members of this Association to control in their due course of business; and

WHEREAS, experience in such control has shown that waste can be reduced without any injury to the water users by the employment of adequate methods of control; and

WHERAS, such useless waste not only extends the adequacy, but also reduces the cost of operation of the works, gives better service and better pressure, not alone for ordinary uses, but during fire and emergencies; and

WHEREAS, to obtain a pure supply from a source where surface water is used, modern practice suggests the employment of water filtration, particularly where pollution is possible and where turbidity may be encountered, and such filtration becomes far more practicable and is much less expensive to the users of water where the waste has been eliminated;

Now, Therefore, Be It Resolved, that it is the sense of the American Water Works Association assembled in convention in Chicago on June 6 to 11, 1927, that it should be the policy of all water works to reduce waste, whether such waste occurs through leakage in mains, wasteful use or other causes; and that such policy will increase the usefulness of the works by giving better service, and make it easier and more practicable to finance, build and operate water supply works, and filter the water supply, if need be.

RESOLUTION ENDORSING ACTION OF FLOOD CONTROL CONGRESS

WHEREAS, we, members of the American Water Works Association, are in convention assembled at Chicago considering matters relating to the water supply and problems of municipalities; and

WHEREAS, in the past two months record floods have occurred on the Mississippi River and its tributaries bringing untold suffering to great numbers of human beings and loss of property, amounting to a great catastrophe, and

WHEREAS, many of our members are operating water works on the Mississippi River and its tributaries which have been threatened or seriously damaged or put out of operation by the present floods; and

WHEREAS, a flood control congress was called by the Mayors of Chicago, New Orleans and St. Louis, which met in Chicago last week and was attended by public officials, engineers and representatives of all parts of the Mississippi Valley; and

WHEREAS, said Congress deliberated at length on the problems involved, and as a result passed certain resolutions;

Now, Therefore, Be It Resolved, that the American Water Works Association do endorse said resolutions which are as follows:

WHEREAS, the time is here for the Federal Government to attack the flood problem in a broad and comprehensive way because of the present Mississippi Valley disaster, the greatest of its kind in the Nation's peace time history, resulting in an incalculable amount of damage to life and property, and

WHEREAS, the need for a comprehensive plan of National flood control is made apparent by this disaster and there are in general three major proposals for flood relief set up by competent authorities, viz., levees, spillways or by-pass outlets and storage reservoirs, all of which should be considered, and

WHEREAS, it is contended that this problem cannot be adequately met by the application of any single remedy and that levees, spillways and reservoirs should be used in combination where practicable, together with such additional remedies as may from time to time be developed; and

WHEREAS, floods in the Mississippi basin have not only brought disaster to those immediately concerned, but have resulted in economic loss to the

whole nation, and the people of this country now demand that effective and permanent remedies be applied and they will willingly approve the expenditures of the public money necessary to this end.

Therefore, Be It Resolved, that the Flood Control Conference, assembled at Chicago, Illinois, does hereby declare that the control of the flood waters of the Mississippi River and all its tributaries is a national problem and that the sole responsibility therefor should be assumed by the National Government; and

Resolved Further, that we urge immediate and effective relief be extended to all present sufferers; that the measures which may be recommended by existing federal agencies for relief to the lower valley, so as to protect it against a recurrence of the present disaster, be carried out promptly, and that the necessary appropriations therefor be made, and

Resolved Further, that, without delaying the carrying into execution of such imperatively necessary measures as may be recommended by existing governmental agencies, the President of the United States is requested to call a Conference for the purpose of formulating, in conjunction with such governmental agencies, a comprehensive plan for navigation and permanent flood control; said Conference to be composed of army engineers, civil engineers, conservationists, geologists, financiers, agriculturists and other experts representing the various interests of our country, and

Resolved Further, that the Conference petitions the President of the United States and the Congress to energetically undertake and carry to a speedy conclusion comprehensive and effective measures for permanent flood control of the Mississippi River and all its tributaries.

RESOLUTION ENDORSING CONTINUANCE OF AMERICAN COMMITTEE ON ELECTROLYSIS

WHEREAS, the American Committee of Electrolysis has requested a referendum to its constituent members as to its continuance, and

WHEREAS, your Committee representing the A. W. W. A. on the American Committee of Electrolysis believes, in view of recent trends in Electric Distribution, it is advisable to continue said Committee and to reaffirm the societies basic position on certain phases of the electrolysis problem.

Therefore, Be It Resolved, by the American Water Works Association in Committee assembled; (1) That this Association endorse the continuance of the American Committee on Electrolysis as a proper agency for promoting inter utility contact and coöperation on electrolysis matters and for the study and consideration of general engineering aspects of the electrolysis and soil corrosion problems, fostering of research along these lines and keeping in contact with all activities in the electrolysis and soil corrosion field, and further

Be It Resolved, (2) That this Association on fundamental engineering grounds definitely opposes the use of pipe drainage as a primary method of electrolysis mitigation, but has no serious objections to its use as a supplementary mitigative measure in situations where the railway, or other distribution systems have obtained their maximum operating economy by the

adoption of suitable primary methods and where pipe drainage can be shown to be the most practical means of taking care of any small residual stray current.

RESOLUTION MODIFYING STAND OF ASSOCIATION AS TO THE USE OF GROUNDING OF SECONDARIES OF LIGHTING TRANSFORMERS

WHEREAS, this Association in 1920 endorsed the grounding of the secondaries of lighting transformers on water pipes as promoting the safeguarding of life and property without hazard to the pipe systems, and

WHEREAS, experience with certain grounding practices, and certain trends in electrical distribution methods has shown that hazards to pipe structures and to water works employees have been and will be set up; and

WHEREAS, certain trends in water works construction methods may seriously affect the conductivity of the water piping systems;

Be It Resolved, that the American Water Works Association in convention assembled hereby modifies its 1920 endorsement of the grounding of the secondaries of lighting transformers as follows:

(1) The American Water Works Association approves the practice of grounding the secondaries of lighting transformers on water pipes for the purpose of safeguarding life and property, provided that appreciable electric current flows over such ground connections only during comparatively short and infrequent intervals when the ground connections are fulfilling their specific protective purposes, and provided that such ground connections impose no responsibility upon the pipe owning company.

(2 The American Water Works Association is opposed to the use of water pipes as electrical conductors, except as noted above, and since experience with certain power distribution practices which have come into use has shown that grounding may result, and in many cases has resulted in hazard to the pipe structures and water works employees, it hereby withdraws its former general endorsement of grounding on water pipes.

At this point Mr. Hinman again assumed the chair and the symposium on Well Water Recessions was resumed. The papers concluding this subject, which were completed at the Friday morning session, were: Application to Iowa, James H. Lees;[5] to Wisconsin, Leon Smith; to Indiana, Charles Brossman; "Sanitary Safeguards in Development of Ground Water Supplies," by W. Scott Johnson, and "Analysis and Tests for Capacity of Water Supplies from Sand and Gravel Formation," by W. G. Kirchoffer.

James E. Gibson reported progress as chairman of the committee on Steel Standpipes and Water Towers.

President Cuddeback expressed great appreciation of the manner in which the members had supported him during his administration

[5] Journal, September, 1927, page 314.

and especially in this convention. He then called the President-elect, James E. Gibson, to the chair.

President Gibson announced that the executive committee had decided that the 1928 convention would be held on the Pacific Coast.

The Nicholas Hill cup, for the greatest percentage of increase in section membership during the year, was awarded to the Florida Section. In doing so, President Gibson referred to the large membership of the California Section, which has grown to be one of the largest sections of the association.

A paper on friction losses in cement-lined and tar coated pipe was read by Melvin L. Enger.[6]

SUPERINTENDENTS' ROUND TABLE DISCUSSIONS

Round Table Discussions under the auspices of the Plant Management and Operation Division, were held in the Crystal Room on Thursday and Friday afternoons, with W. S. Patton, in the chair. At the meetings the printed questions were taken up and thoroughly discussed. A number of other matters of interest to superintendents and operators were considered.

Banquet and Dance. On Thursday evening, June 9, a banquet and dance was held in the Grand Ball Room of the Sherman, considerably over two thousand being present. A toast was offered by John W. Alvord to the Old Water Tower in Chicago, the hall being darkened and a representation of the tower, illuminated with spot light and flanked by the American and Canadian flags, being shown. Dancing till the early hours of the morning concluded the entertainment, under the auspices of the Water Works Manufacturers' Association.

The ladies were given a bus ride through parts of Chicago, with luncheon at the Edgewater Beach Hotel. The bus ride was with the compliments of the local committee and the luncheon with compliments of the Water Works Manufacturers' Association in charge of Mrs. W. C. Sherwood and committee.

Morning Session, June 10. Five papers were read. "Modern Pumping Station Design and Its Probable Future Development," by A. L. Mullergren.[7] "Present Day Tendency to Use Electric Pumps as Standbys in Steam Operated Stations," by D. E. Davis; "Water Hammer, Its Cause and Control," by Loran D. Gayton;

[6] This Journal, page 409.

[7] Journal, August, 1927, page 180.

"Protection of Sub-Surface Structures Against Freezing," by S. L. Bleich. "The Graphic Water Level Recorder—An Aid to More Efficient Operation of Reservoirs and Filter Plants," by G. C. Covert.

Afternoon Session, June 10. The following papers were read. "The Story of Chlorine," by Robert T. Baldwin;[8] "Recent Developments in Water Pipe," by Ralph R. Silver; "Sedimentation Studies of Turbid American River Waters," by A. W. Bull and G. M. Darby; "Seven Years' Observation of Slow Sand and Mechanical Filtration at Toronto," by A. U. Sanderson.

The final number on the program was the progress report of Committee No. 3, on "Practicable Loadings for Purification Processes." This was read by the Chairman, H. W. Streeter.

BOILER FEED WATER STUDIES MEETINGS

Morning Session, June 8. The papers read were "Progress Report of the Activities of the Boiler Feed Water Studies Committee for 1926 and 1927," by Sheppard T. Powell; "Priming and Foaming of Boiler Waters," by C. W. Foulk; "Boiler Feed Water Treatment from a Manufacturer's Viewpoint," by J. B. Romer; and "Zeolite Water Treatment in a Large Central Heating Plant," by Alfred H. White, J. H. Walker and Everett P. Partridge.[9]

Afternoon Session, June 8. "The Value of Boiler Water Treatmnet to the Mechanical Department," by J. F. Raps; "Water Treatment from the Standpoint of Railroad Efficiency," by E. M. Grime;[10] and "Treatment of Locomotive Feed Water from the Chemical Standpoint," by W. M. Barr.

All of these papers were freely discussed.

WATER PURIFICATION DIVISION

The first gathering of the Water Purification Division was at a dinner in the Bal Tabarin of the Hotel Sherman on June 8, at 7:30 p.m. One hundred and thirty eight were present. N. J. Howard presided. The members entertained themselves under the leadership of Wm. J. Orchard. Brief addresses were made by the Chairman and Edward Bartow, Arthur E. Gorman, Jack J. Hinman and Harry E.

[8] This Journal, page 417.

[9] Journal, August, 1927, page 219.

[10] This Journal, page 432.

Jordan. A business session followed. A motion by R. C. Bardwell that "The Chairman appoint a committee of five to study, criticize and suggest additions to the sections of the Manual relating to water purification, and report to the Division at its next meeting" was passed. This committee is understood to function as a part of the general committee on study of the Manual of which Frank C. Jordan is Chairman. It was left to the incoming Chairman to appoint the committee. A discussion followed concerning the activities of the section and methods that might be used to improve its activities.

The technical sessions of the Division were held on June 9 and 10 and the papers presented were as follows:

Morning Session, June 9. "Note on the Decolorization of Soft Waters," by Robert Spurr Weston. "Sodium Aluminate Solution as an Adjunct to Alum Coagulation," by C. H. Christman. "Studies of Double Coagulation at Cincinnati," by Clarence Bahlman. Discussion opened by F. Holman Waring. "New Developments in Water Softening," by C. P. Hoover. "Pre-sedimentation and Basin Detention at St. Louis," by John D. Fleming. 250 present.

Afternoon Session, June 9. "Some Operating Problems in Connection with Purification of Lake Michigan Waters," by Paul Hansen. "The Extension of Aeration in Water Purification," by W. S. Mahlie. Discussion opened by Wellington Donaldson. "A Review of Differential Methods for the Coli-Aerogenes Group of Bacteria," by S. A. Koser. "The Study of the Significance of the Test of Capillarity of a Sand as a Measure of Its Permeability," by R. G. Tyler. "The Graphic Presentation of Analytical Data and a Novel Method of Reporting such Data by Means of Graphs and Charts," by A. J. Authenreith. 250 present.

Morning Session, June 10. Gas Wastes, Symposium on Tastes and Odors. "Coöperative State Control of Phenol Wastes Pollution on the Ohio River Watershed," by E. S. Tisdale. "Progress in Control of Oil Pollution," by Almon L. Fales. "Some Quantitative Studies of Phenols in Water Supplies," by Wellington Donaldson and R. W. Furman. "Recent Improvements in the Art of Pre and Super-Chlorination," by Linn H. Enslow. Discussion by Paul Hansen, D. H. Rupp, A. E. Gorman, D. M. Bakke, F. Holman Waring, C. R. Cox and H. E. Moses. Progress Report on Committee on Standard Methods of Water Analysis, by Jack J. Hinman, Jr. 200 present.

At the close of the session on June 10, the nominating committee,

consisting of F. W. Green, Charles R. Cox and Almon L. Fales (Chairman), reported their suggestions for officers of the division as follows:

For chairman, Wellington Donaldson;

For vice-chairman, Wilfred F. Langlier;

For secretary-treasurer, Harry E. Jordan;

For executive committee, William Gore, George Spaulding and Norman J. Howard.

Their election was moved and carried unanimously.

ABSTRACTS OF WATER WORKS LITERATURE

FRANK HANNAN

Key: American Journal of Public Health, **12**: 1, 16, January, 1922. The figure 12 refers to the volume, 1 to the number of the issue, and 16 to the page of the Journal.

The Softening of Hard Waters. P. WIEGLEB. Z. Spiritus-ind, **49**: 10. 14–5, 1926. From Chem. Abst., **20**: 1876, June 10, 1926. Methods for determining hardness and eliminating lime salts described. Sodium chloride in presence of magnesium oxide is harmful, as magnesium chloride formed is hydrolyzed to hydrochloric acid, which attacks iron, forming iron chloride, which, in presence of oxygen, generates more hydrochloric acid. Iron usually exists in water as ferrous carbonate, which is converted to ferric hydroxide in presence of oxygen, liberating carbon dioxide. Water containing much iron and oxygen should therefore not be used, as corrosion will result. Oxygen is removed by adding iron.—*R. E. Thompson.*

Lime—Its Use in the Treatment of Industrial Wastes. S. E. COBURN and E. S. CHASE. Rock Products, October 31, 42–3, 1925; Pub. Health Eng. Abst., March 20, 1926. From Chem. Abst., **20**: 1876, June 10, 1926. Lime is used as precipitant, for acid neutralization, pH control, and as deodorant. —*R. E. Thompson.*

Denitification in Oxidizing Media. E. PARISI. Ann. chim. applicata, **16**: 40–5, 1926. From Chem. Abst., **20**: 1878, June 10, 1926. In purification of contaminated water, the greater the aeration the greater the loss of nitrogen as free nitrogen, because aeration favors the formation of nitrites, which react with amino acids liberating nitrogen.—*R. E. Thompson.*

The Chloramine Treatment of Pure Water. B. A. ADAMS. Medical Officer, **5**: 6, 55–7, 1926; Pub. Health Eng. Abst., March 20, 1926. From Chem. Abst., **20**: 2036, June 20, 1926. Chlorine and ammonia, when used in right proportions in water containing phenols, are taste preventive. Sterilization is retarded, but is ultimately more efficient.—*R. E. Thompson.*

Waste and Preservation of Material. H. L. MEURER. Z. Ver. deut. Ing., **70**: 461-7, 1926. From Chem. Abst., **20**: 2035, June 20, 1926. Painting affords only temporary protection against corrosion, because of formation of fine cracks during drying and polymerization of paint vehicle. Pigments themselves often act as catalysts, hastening formation of rust. Shortcomings of galvanizing, sherardizing, electrolytic deposition, etc., are limitations of size

and shape of object that can be treated, non-adherent zinc coating, and formation of intermediate layer of zinc-iron alloy that later causes trouble. Claimed that spray or atomizing process, in which zinc wire is melted by surrounding flame of hydrogen and oxygen, or other inflammable mixture, by use of "pistol" designed for purpose, is free from these objections. When object so coated is to be exposed to corrosive liquids, a further layer of paint is needed.—*R. E. Thompson.*

Purifying Water Blown Off from Boilers. S. Otis. U. S. 1,582,300, April 27. From Chem. Abst., 20: 2037, June 20, 1926. Blown-off water (e.g., from locomotives) while still at high temperature is treated with reagent such as sodium carbonate or lime and with added fresh water, and is then subjected to sedimentation and filtration. Treated water is reused in boiler.—*R. E. Thompson.*

Protection of Concrete Against Alkali. E C. E. Lord. Public Roads, **6**: 251, 1926. From Chem. Abst., **20**: 2056, June 20, 1926. Coating of portland cement cylinders with tar or paraffin protects them from action of 3 per cent sodium sulfate-magnesium sulfate solution over period of two years.—*R. E. Thompson.*

Water for Paper. Jesse E. Minor. Paper Trade J., **82**: 15, 60–2, 1926. From Chem. Abst., **20**: 2072, June 20, 1926. Discussion of effect of pure water on cellulose fibre structure and of effects of salts which occur as impurities in mill water on process of changing raw fibres into paper construction.—*R. E. Thompson.*

The Action of Sulfate Water on Concrete. A Summary of Tests of Specimens Immersed for One Year in Medicine Lake, S. Dak. D. G. Mills. Public Roads, **6**: 174–9, 183, 1925. From Chem. Abst., **20**. 2056, June 20, 1926. Cylinders were immersed for one year in the Lake water, salt content of which was 2.34–4.72 per cent, chiefly magnesium and sodium sulfates. High-alumina and standard portland cement cured in steam at 212°F., were unchanged at end of one year. Standard portland cement cured in water vapor at 155°, 100° and 70°F., showed marked decrease in strength after exposure. In some cases admixture of blast-furnace slag, calcium chloride, Cal, and Ironite improved the resistance.—*R. E. Thompson.*

Analysis of Water for Use in Making of Paper. Jesse E. Minor. Paper Trade J., **82**: 15, 62–5, 1926. From Chem. Abst., **20**: 2072, June 20, 1926. Discussion of standard methods of water analysis with view to simplification and greater adaption to paper-mill use (exclusive of water for steam boilers). —*R. E. Thompson.*

The Adsorption of Soluble Salts Through Corrosion- and Rust-Protective Color Films. Hans Wolff and G. Zeidler. Farbe u. Lack, 1926 184. From Chem. Abst., **20**: 2080, June 20, 1926. Experiments were carried out as follows: Paints were prepared of linseed varnish 90 g., sodium chloride 10 g.,

and pigment 167 g., pigments employed being zinc oxide, lithopone, white lead, micaceous hematite and a high ferric oxide red. Paints were applied on glass panels, dried 12 days and placed in water. The number of hours before 100 per cent of sodium chloride had been dissolved from film was as follows: zinc oxide 180, ferric oxide red 43, lithopone 76. With white lead 98 per cent was dissolved in 384 hours, and with hematite only 66 per cent in 574 hours. No explanation given.—*R. E. Thompson.*

The Shandaken Tunnel. R. W. Gausmann. Proc. Am. Soc. Civ. Eng., 53: 5, 681–706, June, 1927. The Shandaken Tunnel, forming a part of the Catskill Water Supply of New York City, extends between Prattville and Shandaken. It is about 18 miles long, horseshoe-shaped and concrete-lined, with inside dimensions of 11 feet 6 inches in height by 10 feet 3 inches width, and a computed capacity of 650 million gallons daily. The paper recounts the development of the project and the geology of the region. The actual construction work is covered in detail. Seven shafts were used and the tunnel was driven both ways from all shafts except 1. Three methods of driving were used: the top heading, the full-face heading, and the bottom heading. In sound rock most of the tunnel was driven with a top heading with a bench from 40 to 50 feet long. In unsound rock, where support was required up to the face, the full-face heading, combined with a mechanical mucker, permitted the most satisfactory progress. Dupont gelatine low-freeze dynamite was used as it appeared to give the smallest amount of objectionable fumes. The tunnel was lined with concrete throughout, placed from the shafts. It was mixed on the surface, poured through a pipe into cars at the foot of the shart, and hauled to the forms. The invert and side-walls were placed by hand, while the arch was placed with a "concrete gun." The entire tunnel, including the Venturi meter and sluice-gates, cost $12,292,411. —*John R. Baylis.*

Water Department Accounting Methods. W. C. Hail. Public Works, 58: 142–143, 1927. A concise presentation of important requirements of an adequate water department accounting system.—*C. C. Ruchhoft.*

Tastes and Odors in Public Water Supplies. Francis E. Daniels. Water Works, 66: 197–199, 1927. A review of the tastes and odors problem with special reference to tastes caused by fresh water plankton and copper sulphate treatment.—*C. C. Ruchhoft (Courtesy Chem. Abst.).*

Municipal Sanitation in Virginia. Richard Messer. Mun. & County Eng., 72: 122–125, 1927. Over 900,000 people are furnished with chlorinated water and many of the cities are over 90 per cent sewered. For 1925 typhoid death rates per 100,000 in Virginia were as follows: (1) Cities over 25,000, six; (2) Cities 1,000 to 5,000, seventeen; (3) Communities of 500 to 1,000, twenty-eight; (4) Rural, fourteen.—*C. C. Ruchhoft (Courtesy Chem. Abst.).*

Public Water Supplies in Colorado. Dana E. Kepner. Public Works, 58: 168–169, 1927. Colorado has 105 municipal water supplies taken from

surface sources, 80 from ground sources, and 15 from combined sources. Three towns have dual supplies. Hardness varies from 25 to 900 p.p.m. A list of supplies having artificial treatment is given.—*C. C. Ruchhoft* (*Courtesy Chem. Abst.*).

Water Taps by Whom Made and Costs. Anon. Water Works, **66**: 137–139, 1927. Data given as to who pays for the water tap and as to who does the work on it in New York municipalities; compiled by the New York State Bureau of Municipal Information.—*C. C. Ruchhoft* (*Courtesy Chem. Abst.*).

Chlorination Operations at Ashokan Headworks. William W. Brush. Water Works, **66**: 130–133, 1927. Chlorine for the New York City Stations is received in multiple unit tank cars. Each unit weighs 3400 pounds and contains 1 ton of chlorine. Special unloading and handling equipment is described for placing the one ton containers in a vertical position on platform scales in the chlorinator room. These containers reduce the cost of shipment, require less labor in handling, are safer than the 150-pound cylinders and reduce the chlorine cost from 5¼ to 4 cents per pound.—*C. C. Ruchhoft* (*Courtesy Chem. Abst.*).

Chicago's New Intake Funnel. Anon. Water Works, **66**: 183–192, 1927. This project includes 7300 feet of 16-foot tunnel, 9100 feet of 13-foot tunnel, four shafts 12 feet in diameter, one new crib, the destruction of the Two Mile Crib, and the installation of machinery to carry on the tunnel work and operate the system after it is completed. A description of the mining methods, drilling, mucking machine, switching equipment, repair shop, and other details of the construction methods used are given. Detailed cost accounts of the work are kept and several tables of costs which apply to sections of the work are given.—*C. C. Ruchhoft.*

Water Softening at Columbus, Ohio. Charles P. Hoover. Water Works, **66**: 223–224, 1927; Public Works, **58**: 208–209, 1927. Plant operating results showed that the hardness at Columbus could be reduced from 289 to 60 p.p.m. when 5 grains per gallon of alum were used without using any excess of lime or soda ash. It was found cheaper to remove the carbonate hardness with lime than by means of zeolite. However, the non carbonate hardness can be removed by zeolite at a cost one-half that of soda ash treatment. Present plans are to treat the water with lime and alum and, after mixing and passing through settling basins to remove the precipitated carbonates, carbonate it at the end of the settling basins. It will then pass to the filters and part or all of it, depending upon the amount of permanent hardness desired to be removed, will be passed through a zeolite filter.—*C. C. Ruchhoft* (*Courtesy Chem. Abst.*).

Practical Application of Inhibitors in Pickling Operations. F. N. Speller and E. L. Chappell. Chem. and Met. Eng., **34**: 7, 421–3, July, 1927. The action of inhibitors in decreasing rate of attack on metals by acids is discussed. Certain inhibitors give very good protection to the metal while at

the same time reducing the attack on rust and scale very little. Certain organic compounds such as quinoline (C_9H_7N) and quinoline ethiodide ($C_9H_7NIC_2H_5$) are very effective. Experiments indicate that some of the acid sludges which are formed during the sulfuric-acid wash of petroleum and coal tar hydrocarbons are also very effective inhibitors.—*John R. Baylis.*

Removing Rust from System with Piping Acid. Chem. & Met. Eng., **34**: 7, 423–4, July, 1927. Extracts from a paper by Speller, Chappell, and Russell presented before the Am. Institute of Chem. Engrs. at its Cleveland meeting. The rust was cleaned from the inside of the piping of a 35-story office building in New York City. Some of the pipes had stopped up entirely with rust and in others the flow of water had been greatly reduced. A practical means of removing the rust was found in a strong acid solvent which dissolved the rust without injuring the pipe. The plan of cleaning was to cut off a certain section of the piping, drain out the water, and fill the piping with the rust solvent, running it in by gravity from a special connection. The solvent dissolved the rust in from 5 to 6 hours. As the solvent in the pipe was used up in dissolving the rust it was drawn off and more added. At the end of the 6-hr. period the pipes were flushed with clean water. The rust solvent was a strong hot solution of hydrochloric acid to which an inhibitor was added to protect the steel.—*John R. Baylis.*

NEW BOOKS

Water Resources Paper No. 50, The Dominion Water Power and Reclamation Service, Department of the Interior of Canada. Volume deals with the surface water supply of Canada and presents the results of investigations made by the Dominion Hydrometric Survey during the climatic year from October 1, 1924, to September 30, 1925, in the provinces of Alberta, Saskatchewan and Manitoba, extreme Western Ontario and the Northwest Territories comprising the Arctic and Western Hudson Bay Drainage and Mississippi Drainage in Canada. The report contains a short explanation of the purpose and scope of the work and 210 pages of stream flow data, with an index map of the territory included showing the location of gauging stations. The report may be obtained free of charge by application to the High Commissioner for Canada, Canadian Building, Trafalgar Square, London, England, or to the Director of the Dominion Water Power and Reclamation Service, Ottawa, Canada.

Oil Engine Power-Plant Handbook. Published by Oil Engine Power, New York, N. Y. Second Edition. This book deals with oil engine installation essentials, the importance of clean air in engine rooms, the erection and maintenance of alternating current generators, generators for oil engine drives, Diesel and oil engine lubrication, cooling water and its treatment, using heat of exhaust gases for beneficial work, purification of lubricating oil, useful operating hints and diagnosis of various indicating diagrams, routine care of air compressor, gasket and packing materials, valve timing on

four cycle engines, various belt drives for oil engines, oil engine construction and operation—an outline of principles and practice, operating economies, etc.

Erectors, operators and prospective purchasers may gain useful information from this book.—*Huldreich Egli.*

Sketches and Workings of Oil Engines. Julius Kuttner. Freeman-Palmer Publications, New York, N. Y. Written in an extraordinary manner and with clearness. The numerous illustrative sketches are particularly helpful to the student.

Chapter 1 distinguishes oil engines from other internal combustion engines. Their relative efficiencies, working temperatures and pressures are described and diagrammatically represented.

Chapters 2 and 3 are treatises on fuel supply to oil engines. In particular Chapter 2 deals with airless, whereas Chapter 3 deals with air, injection types. In addition to numerous illustrations of spray arrangements, reference is made to several useful papers dealing with the subject. The reproductions of photographs of spray experiments are illustrative. Even though there are diversities of opinions as to the completeness of interpretations regarding "atomizers," there is much useful information in these chapters.

Chapter 4 in particular deals with fuel pumps. The points for and against various designs are well brought out, with good reasoning and useful suggestions. Chapter 5 presents the importance of rigid oil engine frame work and indicates how the latter differs in steam engine practice. Chapter 6 gives various illustrations of framing designs such as are commonly adapted for marine uses.

Chapters 7 and 8 deal with cylinder and water jacket designs, while chapter 9 reviews the arrangement and types of cylinder heads from the viewpoint of relation between design and operation. This topic may be considered as general, but much still remains to be said in regard to preventing cracking of cylinder heads in larger engines.

Piston rings are discussed in Chapter 10. The three succeeding chapters deal with the design of pistons, the influence of the structure having bearing on the type of design, and the importance of timing lubrication of same. Those familiar with this subject will readily understand that the last word has not yet been said in this connection.

Major bearings, considered from the viewpoint of maintenance and adjustment; valve gear fundamentals, illustrated by diagrams and views; typical starting valve and control methods; and reversing systems as found in practice, are discussed in the remaining chapters.

In conclusion, the author's intention was not to give an exhaustive treatise on every subject in the book, but to bring before the reader the principles underlying various designs of oil engines, embodied in a manner interesting not only to engineers and designers, but also to operators, for whom it contains much useful information.—*Huldreich Egli.*

Das Wasser in Der Dampf- und Wärme-Technik. C. Blacher. Leipzig: Otto Spamer. 294 pp. Bd. G. M. 18.0; paper G. M. 16.50. Reviewed in

Chem. and Ind., **45**: 11, 188, 1926. From Chem. Abst., **20**: 1877, June 10, 1926.—*R. E. Thompson.*

Chemische Technologie des Wassers. W. Olszewski. Berlin: Gruyter & Co. 138 pp. R. M. 1.25. From Chem. Abst., **20**: 1877, June 10, 1926.—*R. E. Thompson.*

Étude sur les eaux sulfureuses de Pietropola-les-Bains (Corse). J. Richaud. Montpellier: Impr. Firmin & Montane. 55 pp. From Chem. Abst., **20**: 2037, June 20, 1926.—*R. E. Thompson.*

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Discussion of all papers is invited

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MACHINES FOR WATER CONSUMERS' ACCOUNTING PROBLEMS[1]

By D. C. Grobbel[2]

With the many improvements in methods made in the production and conservation of water, there has likewise been felt among water works executives the necessity of improved accounting methods, especially in that branch of the office work called the "Consumers Accounting." This need is not only felt in privately, but in municipally owned water works. True, privately owned works have been operating, as a general rule, for some years under the public utility commissions and have been conforming with the utility commission uniform system of accounts, and were compelled by law to provide the utility commission with certain accounting information which could be secured only by the use of improved and efficient accounting methods. For this reason, privately owned works were more prompt in studying and setting up improved systems of customer accounting. On the other hand, in the great majority of states, the utility commissions have been prohibited by statute from interfering in the supervision of municipal utilities, and consequently the incentive or compelling power to improve was absent, or at least, was not pressing.

Where no laws prescribed the method of keeping the accounts, the

[1] Presented before the Chicago Convention, June 8, 1927.

[2] Assistant Secretary, Board of Water Commissioners, Detroit, Mich.

incitement to better accounting methods has come from the improvement in the standards of general accounting, or from the fact that the increase in the works' business, on account of the urban growth, made it mandatory that the executive become more thoroughly familiar with other phases, especially the financial, than those applied only to the mechanics of supplying water. A further incentive to the municipal works' executive was to be found in the fact that the executive of the privately owned works had command of a vast amount of detailed knowledge which the municipally owned works' executive did not have, but which he badly wanted. To obtain this knowledge, the executive of the municipally owned works found it necessary, not only to improve his office procedure, but also to make changes in his accounting methods.

The engineer, the supervisor, or the mechanic supplies the data on the physical equipment to the executive. The accountant must perform a like service on the financial conditions and operations. Nor must the accountant be one whit less accurate in his work and statements than the man in charge of the planning, designing or operating of the physical elements of the works. The accountant's work touches all the phases of the works—investments, cost of operation and production, state or municipal regulations and, above all, the accounting relations between the consumer and the works. Certainly, nothing affects the good will of the consumer towards the works as much as accurate methods in keeping these accounts.

The refining of the accounting information needed in the administration of public utilities has been one of constant progress and has called for ever increasing demand for accounting labor. To employ the former type of experienced and reliable accountants at the price such labor commands would manifestly, on account of its cost, be prohibitive if it could be obtained. Information that is desirable, or necessary, has to be obtained and this is impossible with unskilled and cheap labor, unless this labor is given a large amount of assistance that may be called upon to perform certain operations with the least mental effort. This kind of assistance was found in the mechanical equipment.

Having once found that mechanical devices could be used in accounting, the inventive geniuses in the employ of the various office equipment manufacturers began bending their efforts to make these mechanical aids better, more efficient and to a greater extent automatic. For a long time these manufacturers were content to

fabricate their machines for general bookkeeping and to supply the demands of the merchant or manufacturer. Privately owned public utilities, to whom the refinement in accounting information was most needful, sought to make use of these inventions and through their insistent demands, a whole line of equipment, adapted to their uses, has been developed, especially for customer accounting.

The general accounts—balance sheets and other standard financial statements—were similar in their nature to those of other businesses, but some of the subsidiary accounting was vastly different, especially the accounting between the utility, such as water, and the multitude of consumers. These accounts must be absolutely accurate, the statements must be gotten out promptly, must be delivered on a scheduled date and must be intelligible, legible, and above all neat. Privately owned electric, gas and water plants were the first to make use of such consumer accounting methods. Municipal plants were and still are backward in the use of this equipment.

It is not the province of this paper to delve into the underlying causes of this condition, but rather to discuss the use of machines in a water works office in connection with consumer accounting. Detroit was the first of the larger cities to adopt machines for accounting purposes and may now be said to be fully equipped to take care of its accounting, mechanically, in all of its branches, excepting the general books. Billing machines are used for consumer accounting, machines are used for cash postings; abstracting, or checking, is done with machines, addresses are printed on the bills by means of an addressograph, likewise the ledger and route number. By an ingenious device, there is also incorporated in the addressograph an auxiliary printer by which, from time to time, messages from the Department are printed on the bills.

The principal equipment in connection with the keeping of the consumer accounts is the billing machine. Here it may be noted that a ready-made machine does not at all times fit all local conditions, no more than that the same type of pump is suitable for all communities. However, this need not worry the executive who contemplates the installation of such equipment. All manufacturers of this type of office equipment have experts who are conversant with the needs of the water works records in general and who, on request, will make a study of the local needs and be pleased to plan a machine or system for any particular works. Naturally, these manufacturers expect to sell their equipment. At the same time, the manufacturer

does not wish to sell, at the expense of having his system and equipment fail to function properly.

Detroit has been doing real machine billing for the past ten years and the installation of the equipment was the result of the inability to secure competent clerical help at a fair price during the World War. Nor would the Department return to the pre-war status, even should an abundance of cheap labor be procurable, if for no other reason than that the accounts are kept more accurately and the bills are rendered to the consumer in better style and on time, thus making a most favorable impression, and, above all, doing away with numberless complaints on account of inaccuracy and uncertain delivery of bills.

Detroit has today approximately 233,000 active meter accounts, with 1500 flat or assessed rate accounts. The so-called cycle reading of meters is practiced. The readers do nothing but read meters. There is a constant flow of work ready for the billing machines, eight in number. It is expected that shortly, even part of the meter reading work, namely, that of computing the individual consumption, will be done by machine, using some subtracting machines for the purpose of obtaining a total consumption by routes, districts, and areas, to complete the final tie-in with the total consumption, as shown on the billing machines for the same areas.

The billing machines perform the following functions—print date of present reading, the reading, date of previous reading and the previous reading, and the consumption. On the type of machine used, should there be an error in the subtraction, the billing machine automatically locks, preventing a mistake in the billing. Because of the type of rates in force in Detroit, namely, a service charge based on the size of the meter, and a consumption charge, the machine prints the size of the meter and the total amount of the bill. This latter amount is automatically printed on the stub. Provisions are also made to include in the totals, the arrears or miscellaneous charges.

Besides the bill proper, the same operation that prints the bill, prints like information on the abstract sheet, which is used for the purpose of checking and segregating the various kinds of information needed for statistical and control purposes. The machine likewise prints the necessary ledger entries on a card. When the machines were ordered, considerable thought was given to the so-called stub accounting system, as opposed to the ledger card system, which latter system would give a chronological history of the account. The card

system was adopted as being more suitable to conditions existing in Detroit, where the works has a tax lien on the real estate for unpaid water bills.

With the making of the bills, the billing machine carries along both the total of the meter consumption and the amount of money. By breaking down with calculating machines the various consumptions, service charges, arrears, credits and penalties, the correctness of the billing is established. The totals are entered by machine on the control cards. Posting is likewise done by cash posting machines and various segregated totals are received to be posted against the control.

Consumers accounting, by machine, may at first glance appear as something cumbersome to operate and difficult to maintain. However, a short study at close range will soon convince one that every move made is made directly and without any false motions. The information obtained through these movements is the exact information desired. The machines are constructed for that purpose only. Nor is the operation of such a machine difficult, in fact, no more difficult than operating a typewriter or an adding machine, thus allowing the use of boys or girls for this important work.

As stated before, there are a number of types of machines that can be used for customer accounting, some one being suitable for the particular local conditions. Some of the machines are equipped with a regular alphabet, others use only numbers and the symbols or letters necessary to fit the particular system. No office is too large for the use of these machines, nor are there any water works offices so small that a machine, useful for customer billing and other work, cannot be designed.

In conclusion, one water works office, Detroit, is thoroughly sold on machine consumers accounts billing, if for no other reason than that during the last year of the manual billing each employe in the consumers accounting bureau handled 2060 accounts and now each one handles 3650, or an increase, per person, of over 77 per cent. Furthermore, the bills are accurate and neat and the information needed for the general books is readily obtainable and absolutely accurate.

DISCUSSION

C. D. WERNER:[3] The opening paragraph of Mr. Grobbel's paper on "Machines for Water Consumers' Accounting Problems" aptly calls attention to the value and necessity of improved consumers' accounting methods.

In order to appreciate fully the importance of mechanical appliances it should be considered that the solution of these problems has had the attention of mathematicians and inventors for over four thousand years.

The father of the calculating machine was Blaise Pascal, a wonderful French mathematician, who produced the first machine that would carry tens in the year 1641. In 1820 an Englishman by name of C. X. Thomas, built a machine which was called the "Arithmometer." Another Englishman, Charles Babbage, devoted over forty-nine years of his life and more than one hundred thousand dollars in attempting to develop a calculating machine. At the time of his death in 1871, his machine was still unfinished.

It remained for an American, William S. Burroughs, to produce in the year 1888, after eight long years of ceaseless experimentation, the machine which has revolutionized the world's bookkeeping methods.

The application of this machine to consumers' accounting problems marks another milestone along the highway of human progress.

Nothing affects the good will of the consumer as much as accurate methods in keeping records. The public utility billing machine has the advantage of accuracy, speed, durability and economical handling of billing work. Its accuracy and speed are obtained from the automatic features built into the machine, making the work more than 75 per cent automatic. Machine entries on ledger record, bill and cashier's stub are all orginal entries, the figures printed on bill being automatically repeat printed on cashier's stub as well as ledger record. The machine is equipped with a lock to prevent change of figures during this repeat print operation.

We are all thoroughly conversant with the fact that the successful operation of the so-called pen and ink systems depended entirely on the former type of experienced and reliable bookkeepers. Now that this type of office help is no longer available we have turned to the

[3] Public Service Division, Burroughs Adding Machine Company, Detroit, Mich.

mechanical aids to give us the same feeling of satisfaction and security.

Monthly statements to customers must be easily understood, legible and, above all, *neat*. How can we best fulfill these requirements? Only by the use of the public utility machine, because it writes bills that are neat, legible and businesslike in appearance. In addition, it proves the bill for correct writing and charge.

The first information that must be secured is the posting media, the flow of the work, and the information furnished to the customer on the statements. Hence the four most important consumers' accounting records are: (*a*) rate schedule, (*b*) meter read sheet, (*c*) ledger record, (*d*) consumer's bill.

Before attempting to find the correct solution to your problem it it is necessary to study the posting media and decide how to handle the work by machine, as well as the method of proving the work. The posting media, together with the rate structure, will determine the style of machine to use.

Next we must know the number of meters billed each month in order to gauge the volume of work. The type of rates will determine whether we can use billing charts satisfactorily.

From the actual meter read sheets, ledger records and bills, we can obtain the information furnished by the meter reader, method of delivering the bills, method of dating bills to show reading dates as well as discount dates, the space required for the addressograph impression on both bill and stub, also the present method of posting both debit and credit entries to the ledger record.

Next we must make the necessary provision to prove to the general ledger control as well as obtain the essential distribution and statistical information.

In considering the application of machines to consumers' accounting problems, it should be thoroughly understood that, no matter what type of plan is decided upon, the machine operations can be simplified and greater accuracy will be secured by making use of the following desirable features:

a. Automatic cross tabulating carriage. An automatic tabulating motor returned carriage is an important factor in any machine's speedy handling of billing. The machine must automatically tabulate through the various printing positions, stopping at the right place for each entry, then moving on to the next position, all without any attention from the operator. In addition, the machine should

automatically return to first printing position at the completion of each bill.

b. Automatic repeat print. The billing machine repeat prints the items and totals, entered on the bill, as original entries on both ledger and cashier's stub, thereby eliminating the use of carbon records.

c. Automatic writing line finder. This feature causes both bill and ledger to drop into pre-determined writing position without any effort on part of the operator.

d. Automatic opening of throat. This device automatically causes the carriage platen to release the bill and ledger at the completion of each bill for easy removal and insertion of the next consumer's records.

e. Decimal position. Irrespective of the amount set up on the keyboard the machine should automatically select the proper decimal position.

f. Automatic printing of totals. In order to prevent the possibility of copying amounts incorrectly both bill and long totals should be secured by merely depressing total key.

The use of the public utility machines for consumers' accounting work by the City of Detroit Water Department has brought about the following results:

1. Every bill proved before leaving the office.
2. Neatness and legibility of bill improved.
3. Tabulation of income as a by-product of billing.
4. Debit posting a by-product of billing.
5. Ledger record is an exact copy of consumer's bill as rendered.
6. Accounts Receivable ledgers balanced before bills are delivered.
7. Absolute proof of credit posting.
8. Increase of over 77 per cent in the number of accounts handled per employee.

The one common difficulty among all public utility executives, when they are brought face to face with the inadequacy of their present system of handling consumers' accounts, is *lack of time.* The ever increasing pressure of routine duties prevents them from making the careful analysis necessary to solve their own problems. What is the remedy for this condition? Bring in someone whose business it is to plan just such improvements. The manufacturer of this style of office equipment has developed a trained force of experts whose services are now available and who will make the necessary study of your problem and offer recommendations as to the type of mechanical equipment to be used.

REVISED INTERSTATE COMPACT AS TO THE WATERS OF THE DELAWARE RIVER[1]

The Commonwealth of Pennsylvania, the State of New Jersey and the State of New York having appointed as commissioners, for the purpose of negotiating a compact with respect to the water resources of the Delaware river,

CHARLES H. MINER ROBERT Y. STUART PHILIP P. WELLS	*For the Commonwealth of Pennsylvania*
WILLARD I. HAMILTON HENRY G. PARKER HARRY BACHARACH S. WOOD MCCLAVE CARROLL P. BASSETT F. MORSE ARCHER EDWARD L. YOUNG	*For the State of New Jersey*
GEORGE MACDONALD RUDOLPH REIMER JEFFERSON DEMONT THOMPSON	*For the State of New York*

the said commissioners, after negotiations, have agreed upon the following articles:

ARTICLE I

This compact, between the sovereign states of Pennsylvania, New Jersey and New York, is entered into to provide for the preservation of the Delaware river and, consistent with such object, to

[1] Revised recommendations proposed by Commissioners representing the Commonwealth of Pennsylvania, the State of New Jersey and the State of New York, January 13, 1927. The original compact proposed, now revised in the form here given, was printed in THE JOURNAL, February, 1925, p. 160. This revised compact was adopted by the State of New York, but no legislative action was taken in New Jersey and Pennsylvania.

enable each of the said states to make use of a part of the waters thereof for the purpose of meeting present and resonably prospective needs. This compact does not allocate the remaining waters nor fix any ratio or principle to govern future divisions.

Article II

Where used in this compact, singular words shall be considered as including the plural, masculine words shall be construed as including the feminine and neuter, and the following terms and expressions shall have the meanings respectively designated for each:

(1) The term "waters of the Delaware river" means the surface waters originating within the Delaware drainage basin.

(2) The term "channel" or "channel of the Delaware river" means the bed of the Delaware river and the lands on and over which the waters of said river flow, beginning at the place where said river crosses Latitude forty-two degrees (42° 00′), the northern boundary of the Commonwealth of Pennsylvania, and extending thence continuously as the said river winds and turns down to Latitude forty degrees twelve and one-half minutes (40° 12½′) near Trenton Falls.

(3) The term "Delaware drainage basin" means the total area of both land and water from which the surface waters flow down to where the channel of the Delaware river crosses Latitude forty degrees twelve and one-half minutes (40° 12½′).

(4) The term "Upper Basin" means that part of the Delaware drainage basin from which the surface waters flow down to where the channel of the Delaware river crosses Latitude forty-one degrees twenty-one and one-quarter minutes (41° 21¼′), below the mouth of the Neversink river and near the point which marks the boundary between the Commonwealth of Pennsylvania and the states of New Jersey and New York.

(5) The term "Lower Basin" means that part of the Delaware drainage basin which is not embraced within the Upper Basin.

(6) The term "tributary" or "tributary of the Delaware river" means any watercourse, the waters of which naturally flow into the channel of the Delaware river.

(7) The term "development" means making water available for use or diversion by the construction of any intake, dam or other works.

(8) The term "develop" means to make available by development.

(9) The term "point of storage" means the place on a tributary or in the channel of the Delaware river at which a dam is maintained for the purpose of creating storage.

(10) The term "point of diversion" means the place at which water is diverted from a tributary or from the channel of the Delaware river.

(11) The term "diversion" when referring to the water of a tributary means the taking or removal from that tributary of water which is not returned into the channel of the Delaware river either above the point at which the tributary enters said channel or within a distance of twelve miles below that point, measured along the center line of said channel. When referring to the channel of the Delaware river this term means the taking or removal from said channel of water which is not returned into said channel or into the Delaware river below Latitude forty degrees twelve and one-half minutes ($40^\circ\ 12\frac{1}{2}'$) within a distance of twelve miles below the place of taking or removal, measured along the center line of said channel and river.

(12) The term "divert" means to effect a diversion.

(13) The term "domestic and municipal" as applied to the use of water means the use of water by or for water-works serving the public.

(14) The term "sanitation" as applied to the use of water means the use of water for the conveyance of sewage and other wastes.

(15) The term "industry" as applied to the use of water means the use of water for manufacturing and industrial purposes, other than power, when the water used is not taken from water-works serving the public.

(16) The term "power" as applied to the use of water means all use of water, direct or indirect, for the generation of energy.

(17) The term "navigation" as applied to the use of water means the use of water for transportation and for the operation of water craft.

(18) The term "commission" means the Tri-State Delaware River Commission.

ARTICLE III

For the purposes of this compact the order of importance and public value of water shall be: (A) domestic and municipal, (B) sanitation, (C) industry and power, and (D) navigation.

Article IV

Subject to the duties and obligations imposed by this compact, any administrative department or political subdivision authorized in that behalf by or under the laws of any signatory state, or any corporation, partnership, association or person hereafter so authorized, may exercise the rights and privileges herein conferred on such state in conformity with such other terms and conditions as that state may impose and under such further requirements as the commission may prescribe in the exercise of its authority under this compact.

Article V

Subject to the provisions of this compact, each signatory state may divert water from any tributary of the Delaware river within that state or from the channel or from both. The total quantity which may be diverted by each state in any one calendar year shall not exceed the following:

Pennsylvania—Three hundred twenty-eight and one-half ($328\frac{1}{2}$) billion gallons, which total quantity is equivalent to an average of nine hundred (900) million gallons daily.

New Jersey—Two hundred nineteen (219) billion gallons, which total quantity is equivalent to an average of six hundred (600) million gallons daily.

New York—Two hundred nineteen (219) billion gallons, which total quantity is equivalent to an average of six hundred (600) million gallons daily.

The quantities of water herein authorized to be diverted are in addition to all quantities of water which have heretofore been lawfully diverted by the normal operation of all works existing and in actual operation within each state in the Delaware drainage basin when this compact becomes effective, and the future diversion of water in quantities not exceeding those heretofore lawfully diverted by the normal operation of such works shall not be charged against the total quantity which may be diverted under authority of this article by that signatory state in which said works are located.

Article VI

Diversions allowable under Article V may be made by each signatory state from any tributary of the Delaware river within that state for use either within or without the Delaware drainage basin, subject to the following restrictions and limitations:

(1) Authority for every development shall be obtained, and every development shall be carried out, under the laws of the state in which it is located.

(2) On every tributary from which a diversion is made there shall be provided sufficient storage to insure the reserve flows required by this article.

(3) Within the Upper Basin, at all times during the months of July, August, September and October, there shall be released from storage and delivered into the tributary or into the channel of the Delaware river above the point at which the tributary enters said channel, a reserve flow equal to forty-five hundredths (0.45) of a cubic foot per second for each square mile of drainage area above the point of storage; during the remainder of the year such a reserve flow shall be maintained only on the days when the flow from the drainage area above the point of storage is less than forty-five hundredths (0.45) of a cubic foot per second for each square mile of drainage area above the point of storage.

(4) Within the Lower Basin there shall at all times be released from storage and delivered into the tributary or into the channel of the Delaware river above the point at which the tributary enters said channel a reserve flow equal to fifteen hundredths (0.15) of a cubic foot per second for each square mile of drainage area above the point of storage.

Article VII

Diversions allowable under Article V may be made by each signatory state from the channel of the Delaware river for use either within or without the Delaware drainage basin, subject to the following restrictions and limitations:

(1) All diversions shall be made in accordance with schedules which shall be prescribed from time to time by the commission. In the Upper Basin said schedules shall allow to each diverting state at least one-third of the flow over and above the reserve flow requirements; in the Lower Basin said schedules shall allow to each divert-

ing state at least one-half of the flow over and above the reserve flow requirements. Any schedule prescribed by the commission authorizing the diversion of more than one-third of the divertible flow in the Upper Basin or of more than one-half of the divertible flow in the Lower Basin shall not operate to create an irrevocable right to continue such excess diversion nor to prevent the commission from at any time modifying or changing any such schedule to allow to each diverting state in the Upper Basin only one-third of the divertible flow or to allow to each diverting state in the Lower Basin only one-half of the divertible flow, or to prevent the commission from at any time modifying or changing any such schedule in any other manner that may be necessary to meet the conditions existing at the time such change or modification is made.

(2) In the absence of storage at the place where the diversion is accomplished no water shall be diverted from the channel within the Upper Basin unless the flow in the channel is in excess of a reserve flow of forty-five hundredths (0.45) of a cubic foot per second per square mile of drainage area above the point of diversion. In every diversion, in the Upper Basin, made from a storage reservoir lying wholly or in part within the channel, a reserve flow equal to forty-five hundredths (0.45) of a cubic foot per second per square mile of drainage area above the point of storage shall be maintained at the point of storage at all times when the flow in the channel from the drainage area above the point of storage is greater than that amount; when the flow in the channel from the drainage area above the point of storage is less than forty-five hundredths (0.45) of a cubic foot per second per square mile, then a reserve flow equal to the flow from the drainage area above the point of storage shall be maintained in the channel at the point of storage.

(3) In the absence of storage at the place where the diversion is accomplished no water shall be diverted from the channel within the Lower Basin unless the flow in the channel is in excess of a reserve flow of twenty-four hundredths (0.24) of a cubic foot per second per square mile of drainage area above the point of diversion. In every diversion, in the Lower Basin, made from a storage reservoir lying wholly or in part within the channel, a reserve flow equal to twenty-four hundredths (0.24) of a cubic foot per second per square mile of drainage area above the point of storage shall be maintained at the point of storage at all times when the flow in the channel from the drainage area above the point of storage is greater than that amount;

when the flow in the channel from the drainage area above the point of storage is less than twenty-four hundredths (0.24) of a cubic foot per second per square mile, then a reserve flow equal to the flow from the drainage area above the point of storage shall be maintained in the channel at the point of storage.

(4) The reserve flows required under this article at every point of diversion or of storage shall be in addtion to water in transit which may be flowing in the channel at such point.

(5) Every storage reservoir lying wholly or partly within the channel of the Delaware river shall at all times be operated so as not to interfere with or retard the free passage of water in transit, of the required reserve flows and, except as otherwise permitted by the schedules prescribed by the commission, of that part of the flow in the said channel which may not be diverted by the state under the authorization of which state said storage reservoir was constructed.

Article VIII

Each signatory state may authorize an appropriate department to designate as water in transit for the use of that state any or all water that has been or may hereafter be developed by storage for any purpose by or under the authorization of such state either on any tributary within said state or on the channel of the Delaware river. All water so designated shall be known as "water in transit" and may be permitted to flow into and down the channel of the Delaware river. All water which has been so designated shall be considered as having been diverted at the point of storage where it was developed and shall be charged against the total quantity of water which may be diverted by the designating state under the authority of Article V.

Water in transit may be removed from the channel of the Delaware river by or under the authority of the designating state. The daily rate at which water in transit may be removed from the channel shall not exceed the daily rate at which it is delivered and no greater quantity of such water may be removed than shall have been delivered into the said channel. All water in transit shall be subject to the reserve flow requirements of Articles VI and VII which apply at the point of storage where said water was developed. In the case of water in transit from any development completed prior to the date when this compact becomes effective said reserve flow requirements shall, so long as the existing authorization for such development

continues in effect, apply only at times when water in transit from such development is actually flowing in the channel of the Delaware river.

Every designation of water in transit made under the authority of this article shall be evidenced by the filing with the commission of a declaration setting forth the contemplated uses of said water and any such designation may at any time be withdrawn or amended without prejudice to its subsequent amendment or renewal. Notice of every amendment or renewal shall be given to the commission through the filing of a declaration, the provisions of which declaration shall not become effective until two years from the date of the filing thereof unless the commission shall, after hearing, fix an earlier date.

Article IX

With the approval of the commission each signatory state may build dams entirely or partly across the channel of the Delaware river upon such terms and conditions as the commission, after hearing, may prescribe.

All such dams shall be built so as to conform to the requirements relating to physical construction and safety in the state or states in which they are located and shall at all times be operated so as not to interfere with any diversion that is in accordance with schedules prescribed by the commission nor with any water in transit.

Article X

Notice of every development for diversion from any tributary shall be filed with the commission, prior to the beginning of construction, by the state in which the development is located or by the holder of the authorization for such development; said notice shall include a statement of the quantity of water proposed to be diverted, the purpose of such diversion and a copy of the authority for the development.

Article XI

To evidence that the provisions of this compact are being complied with there shall be installed and maintained, in connection with every development which comes under the provisions of this compact,

adequate and suitable equipment for measuring all necessary quantities and rates of water flow. Records of all water flows in connection with such developments shall be kept and furnished to the commission as the said commission may require. Said equipment shall be installed and maintained and said records shall be kept and furnished by the state or by the holder of the authorization for every such development.

Article XII

No water from the Delaware drainage basin shall be diverted for use outside the boundaries of the states signatory to this compact. Except by legislative act no signatory state may give, grant or dispose of to another signatory state, or to the holder of an authorization therefrom, any water allotted to it or developed by it under the provisions of this compact. The joint exercise by or under the authority of two or more of the signatory states of any right under this compact is hereby authorized.

Article XIII

The signatory states, recognizing the importance of conserving the sanitary quality of the waters flowing in the channel of the Delaware river so that these waters may be used as sources of domestic and municipal water supplies, agree to co-operate in carrying out a policy for maintaining said waters in a sanitary condition at least equal to that which obtains as of the date when this compact becomes effective.

Article XIV

The beneficial effects of forest covered areas on the regularization of stream flow, with attendant greater potential use of streams for domestic, industrial, navigation and other purposes, are recognized by the signatory states. Each signatory state agrees to adhere to a policy covering the establishment and maintenance of an adequate forest cover in the Delaware drainage basin and the maintenance of the highest practicable standards of protection from fire on these lands.

Article XV

Each signatory state, in the exercise of any right under this compact, may take and condemn any property necessary for the construction, maintenance and operation of any dam in or across the channel of the Delaware river. Each signatory state may also take and condemn any rights to the use of or in water, the taking or condemnation of which rights is necessary to effect any allowable diversion made under this compact from any tributary or from the channel of the Delaware river. The power of condemnation herein conferred shall be exercised in accordance with the laws of the state in which the property or the rights to be taken or condemned are located. Any such property and rights, though devoted to a public use, may be taken and condemned in favor of any public use higher in the order of importance set forth in Article III.

Article XVI

All damage to persons or property resulting from the exercise of any rights under this compact shall be determined under the rule of damages, in accordance with the procedure, and in such manner as is provided by the law of the state in which the damages are suffered. The damages suffered in the State of Pennsylvania shall be ascertained, recovered and paid as provided by the forty-first section of the act approved April twenty-ninth, one thousand eight hundred and seventy-four (Pamphlet Laws 73) and the amendments and supplements thereto or any substitute therefor in effect when the development is authorized. The damages suffered in the State of New York or in the State of New Jersey shall be ascertained, recovered and paid as provided by any general or other now existing act applying thereto or any substitute for the same in effect when the development is authorized. The court or courts which have jurisdiction of the subject matter in the respective states shall have jurisdiction of the person of every party in interest for the purpose of notice, summons and hearing throughout all three signatory states.

Article XVII

Any property of a signatory state or of the holder of an authorization of such state, acquired in the exercise of any right or privilege under this compact, which is located in any other signatory state

shall be subject to taxation as private property under the general laws of the state in which it is located.

Article XVIII

Nothing in any existing treaty or compact between any two of the signatory states shall be modified or changed or invalidated by anything herein contained except in so far as the same is repugnant to any provision of this compact.

Article XIX

The Tri-State Delaware River Commission is hereby created as a body corporate to consist of not more than three members from each of the signatory states. Each state may, by appropriate legislation, provide for the designation, appointment and tenure of its members. Until such time as a signatory state shall by legislation otherwise provide, the Governor of such state is hereby directed to designate an appropriate officer or employee and may appoint not more than two other persons to represent said state as members of the Tri-State Delaware River Commission.

Each signatory state shall have one vote in the commission. Every decision, authorization or approval of the commission shall require a unanimous vote of the states entitled to vote thereon. On matters pertaining only to the Lower Basin, the State of New York shall have no vote.

Every decision, authorization or approval rendered shall be accompanied by a certificate of the commissioners that the same is, in their judgment, in the public interest and such certificate shall state the reasons on which the decision, authorization or approval is based.

The powers and duties of the commission, in addition to those hereinbefore set forth, shall be:

(1) To make rules and regulations for the organization and the conduct of its business.

(2) To report annually to the governors for the information of the legislatures of the signatory states as to the developments under the terms of this compact and as to such other matters as may come within the purview of the commission.

(3) To report in like manner at intervals of not more than five years as to the existing and reasonably prospective needs of the

signatory states and the extent to which and the manner in which each signatory state has exercised its rights under this compact.

(4) To observe the operation of all developments; to make such orders in writing after hearing as may be necessary to secure compliance with those provisions of this compact which are within the jurisdiction of the commission; and to institute any appropriate action or proceeding at law or in equity to enforce compliance with such orders and with the terms and conditions imposed in any decision, authorization or approval made by it.

(5) To require by order in writing compliance with Article XI.

(6) To make, modify and change the schedules referred to in Article VII.

(7) To make such examinations as may be necessary to ascertain the quantities of water heretofore lawfully diverted by the normal operation of all works existing and in actual operation when this compact becomes effective.

(8) The commission or any member thereof or any employee or other person duly authorized thereby is hereby empowered to enter without let or hindrance upon the lands and property upon which any development is being constructed, operated or maintained under this compact. Each state through its appropriate departments shall coöperate with the commission in obtaining such data, information and records as may be necessary in the performance of its duties.

(9) Whenever, by this compact, provision is made for action by the commission after hearing, notice of such hearing shall be given to the governor of each state at least ten (10) days before the date set for such hearing.

(10) The attorney general of each signatory state or a deputy or assistant shall serve as the legal adviser of the commissioners representing that state.

(11) The commission is authorized to provide suitable offices and conveniences for the transaction of its business and to employ such technical and clerical assistance as may be necessary to enable it to carry out the duties imposed by this compact. The expenses of the commission shall be paid, share and share alike, from funds provided by each of the signatory states in such manner as the laws of the signatory states shall prescribe.

Article XX

Notwithstanding anything contained in this compact, each state may institute any action or proceeding at law or in equity for the enforcement or protection of its rights or the rights of its citizens accruing under this compact or otherwise.

Article XXI

The governors of the signatory states—upon the request of any one of them, shall each forthwith appoint a commissioner, and the said commissioners are empowered to consider and recommend modifications of this compact and upon adoption by the legislative act of each and all of said states, the Congress of the United States having consented thereto, such modifications shall be in full force and effect.

Article XXII

Should any part of this compact be held to the contrary to the constitution of any signatory state or of the United States all other severable parts of this compact shall continue to be in full force and effect.

Article XXIII

The consent of the Congress of the United States to this compact shall in no wise affect any existing Federal statute.

Article XXIV

This compact may be terminated at any time by concurrent legislative action of all the signatory states. In the event of the termination of this compact all rights which may have become vested under its provisions shall remain and continue unimpaired.

Article XXV

This compact shall be submitted for adoption to the legislature of each of the signatory states at the several sessions beginning in the month of January, nineteen hundred and twenty-seven; and upon adoption by the legislative act of each and all of said states the Congress of the United States having consented thereto, it shall be in full force and effect.

In Witness Whereof, the commissioners have signed this compact in triplicate originals, one of which shall be deposited with the Secretary of State of each of the signatory states.

Done at The City of New York, New York, this thirteenth day of January, in the year of our Lord, one thousand nine hundred and twenty-seven.

Charles H. Miner
Robert Y. Stuart
Philip P. Wells
Willard I. Hamilton
Henry G. Parker
Harry Bacharach
S. Wood McClave, Jr.
Carroll P. Bassett
F. Morse Archer
George MacDonald
Rudolph Reimer
J. D. Thompson

NEW YORK CITY'S FUTURE PROPOSED WATER SUPPLY FROM THE DELAWARE RIVER[1]

Under date of October 9, 1926, the Board of Water Supply recommended the approval of a plan for securing an additional supply of water from Dutchess, Columbia and Rensselaer counties. This plan recommended the best of those sources of supply which at that time appeared to be available and eliminated reference to the waters of the Delaware river, which were then the subject of discussions between Commissions representing the states of New Jersey, Pennsylvania and New York. These commissions completed their labors on January 13, 1927, and unanimously agreed upon a form of compact[2] providing for an apportionment of the waters therein referred to, which came before the legislatures of the three states at their respective sessions, recently concluded.

This form of compact was adopted by the legislature of New York and duly signed by the Governor. In New Jersey and Pennsylvania no legislative action was taken. In Pennsylvania the power and authority of the compact commission terminated with the submission of its report and there is now no body formally authorized to represent that state. The legislature of Pennsylvania does not again meet in regular session until January, 1929. It is evident, therefore, that no determination under said compact relating to the waters of the Delaware river can be had for a number of years to come.

The urgency of proceeding in this matter of securing an additional supply of water is compelling. Further delay is fraught with risk. Four years have already elapsed since the first steps looking toward a formal compact with respect to the waters of the Delaware river were taken. During this period two forms of compact were negotiated but the legislation necessary to the confirmation of either was not had. The city should not wait longer. In every sense the best supply for meeting the vital needs of the city is to be found in these

[1] Editorial abstract of Report of Board of Water Supply of New York City to Board of Estimate and Apportionment, July 27, 1927.

[2] Reprinted in full on page 417, This Journal.

waters which have their origin in the state of New York and which are tributary to the Delaware river.

The Board of Water Supply therefore recommended that the Board of Estimate and Apportionment return, without approval, the plan submitted under date of October 9, 1926, and, as a substitute therefor, approve of the following plan, which looks toward the development and utilization of 600 million gallons daily of the flood waters of the following tributaries of the Delaware river: East Branch, Neversink, Little Delaware, Beaver Kill, Willowemoc.

This plan also includes the waters of Rondout creek, a tributary of the Hudson river.

The flood waters of the Delaware will be stored in reservoirs provided for that purpose and conveyed into a reservoir in the Rondout valley, from which place a tunnel deep in the rock and 49 miles long will carry them into the present West Branch reservoir, on the Croton watershed. Another tunnel will extend from the West Branch reservoir to Kensico reservoir and thence to Hill View reservoir, where connection will be made with both the present Catskill delivery tunnel and the new delivery tunnel authorized by the Board of Estimate and Apportionment on March 10, 1927.

Details of the above plan are shown on figure 1, dated June 21, 1927.

The plan proposed for the taking of the flood waters of the Delaware is predicated directly on the form of compact agreed to by the commissioners of the three states on January 13, 1927, which form of compact, moreover, has been sanctioned through its adoption by the legislature of New York and subsequent signature of the Governor. The reservoirs to be constructed under the proposed plan will be operated in such manner as to withhold water from the tributaries on which they are located only when the flow therein is greater than the ordinary flow; at all other times the ordinary flow will be maintained. Moreover, during July, August, September and October, irrespective of the flow in the tributary, water may be released from these reservoirs in such manner that the ordinary flow will be continuously maintained. The effect of so operating the storage reservoirs will, on the one hand, be to diminish the flood flows in the Delaware while on the other the low season flows will be augmented and increased. The increase in the low season flows will thus be in proportion to the dryness of the season,—that is to say, the drier the year, the greater will be the proportionate increase in flow in the Delaware river.

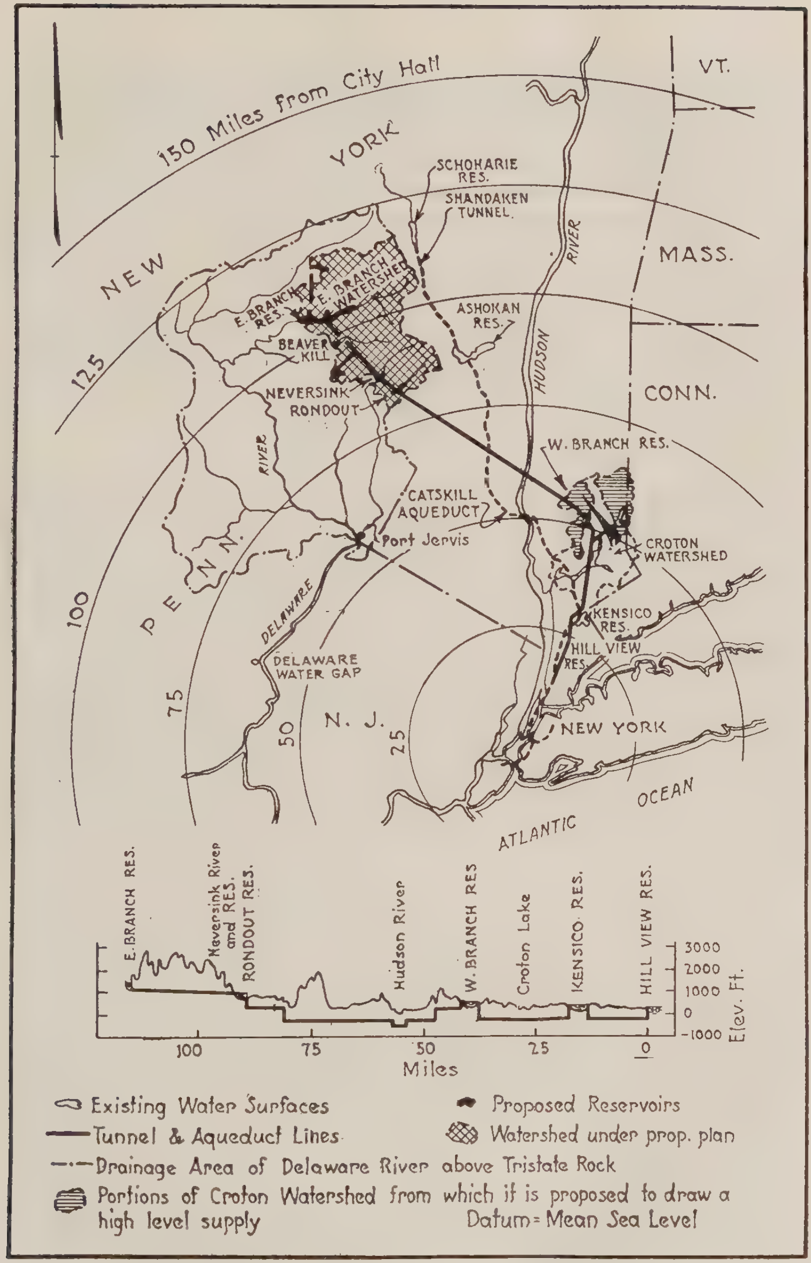

Fig. 1. Plan and Profile of New Water Supply Project for New York City

The plan on which the above stated scheme of operation of the storage reservoirs is based is, in principle, that of storing the waste flood waters of the tributaries of the Delaware and utilizing them both for regulating and increasing the low flows of the Delaware and for supplying the needs and necessities of the city. This plan is fair and equitable to the other states as well as to all municipalities and private persons everywhere along the Delaware river. It will involve no unreasonable interference with the flow in that river and will constitute no more than a fair and just conservation of these now useless waters. It merely represents the exercise by New York of a part of its reasonable and ultimate right in these waters.

In this connection it is of importance to note the following language of the Supreme Court in 206 U. S. 46:

> One cardinal rule, underlying all the relations of the states to each other, is that of equality of right. Each state stands on the same level with all the rest. It can impose its own legislation on no one of the others, and is bound to yield its own views to none. Yet, whenever, as in the case of Missouri v. Illinois, supra, the action of one state reaches, through the agency of natural laws, into the territory of another state, the question of the extent and the limitations of the rights of the two states becomes a matter of justiciable dispute between them, and this court is called upon to settle that dispute in such a way as will recognize the equal rights of both and at the same time establish justice between them. In other words, through these successive disputes and decisions this court is practically building up what may not improperly be called interstate common law. This very case presents a significant illustration. Before either Kansas or Colorado was settled the Arkansas river was a stream running through the territory which now composes these two states. Arid lands abound in Colorado. Reclamation is possible only by the application of water, and the extreme contention of Colorado is that it has a right to appropriate all the waters of this stream for the purposes of irrigating its soil and making more valuable its own territory. But the appropriation of the entire flow of the river would naturally tend to make the lands along the stream in Kansas less arable. It would be taking from the adjacent territory that which had been the customary natural means of preserving its arable character. On the other hand, the possible contention of Kansas, that the flowing water in the Arkansas must, in accordance with the extreme doctrine of the common law of England, be left to flow as it was wont to flow, no portion of it being appropriated in Colorado for the purposes of irrigation, would have the effect to perpetuate a desert condition in portions of Colorado beyond the power of reclamation. Surely here is a dispute of a justiciable nature which might and ought to be tried and determined. If the two states were absolutely independent nations it would be settled by treaty or by force. Neither of these ways being practicable, it must be settled by decision of this court.

New York, in now proceeding to utilize a small portion of the flood waters of these tributaries which originate, and for the use contemplated always remain, on her soil, will merely be moving toward the assertion of a basic and inalienable right in equity. There is no precedent denying the right that is sought to be exercised; there is no statute which forbids it either expressly or by implication.

THE COST OF THE PLAN

The estimated cost of all the constructions necessary to provide a new and additional supply of 510 to 540 million gallons daily delivered into Hill View reservoir, together with similar delivery of 100 million gallons daily of water from the higher levels of the Croton watershed, is $272,587,000.

This cost will be spread over a period of about twelve years.

In the report of the Board of Water Supply of October 9, 1926, it was pointed out that any deficit which may at any time exist can be reduced or entirely eliminated by a suitable revision of the existing water rate schedules. And it should here be remarked that there has been no increase in the water rates since the present schedule was adopted, in 1857.

In connection with the consideration of the financial aspects of this plan, it is to be pointed out that as the expenditures involved in the recommendations presented are for water supply purposes, they will not operate to reduce or impair the debt incurring capacity of the city.

REASONS FOR THE PLAN

The plan herein presented, aside from the considerations already stated, is further based on the following reasons:

1. It is the most economical and will insure a supply of not less than 500 million gallons daily of new and additional water at a saving in cost of more than $75,000,000 over the plan of October 9, 1926, which looked toward obtaining 434 million gallons at an estimated cost of $347,934,000.
2. The water proposed to be secured is pure and wholesome and of excellent quality.
3. The development of this plan will involve a shorter length of aqueduct, fewer reservoirs, the acquisition of a minimum of real estate, the interference with fewer communities and the relocation of a smaller mileage of highways and railroads than under the plan previously submitted.
4. The water which it is proposed to take is the flood water of the tributaries which rise within the sovereignty of the state of New York. These waters,

before they reach the channel of the Delaware river, are wholly and completely within the possession and jurisdiction of the state of New York. The very least right which New York has in them is equal to the right of New Jersey and to that of Pennsylvania. No one of the states should, under any rule of reason or equity, either claim or take all of this water. Neither should any one of them deny to either or both the others the right to use a reasonable share thereof.

5. The plan proposed will cause neither injury nor damage to any person or property along the Delaware river. The flood flows will be reduced and the low season flows augmented. This proposal of increasing the low season flow is, under the circumstances, purely voluntary, but, in their judgment, it accords exactly with the fair and equitable principles which were agreed upon in the forms of compact negotiated and signed by the commissioners of the three states on January 24, 1925, and January 13, 1927.

6. Similarly, the plan proposed does not, in the total quantity of water to be taken, go beyond the *minimum* limit agreed upon in the form of compact dated January 13, 1927.

7. New York has physical possession of the waters which this plan proposes to utilize. These waters now flow unused to the ocean. They benefit no one, and in times of flood are ever a potential source of danger. New York, in possession of these waters, may well use them for the purpose of supplying the needs of her greatest city. Should either or both of the other states feel aggrieved or believe that they will be damaged by the carrying out of the plan as proposed, their only remedy will lie in an action brought in the Supreme Court of the United States. This Court, in many similar cases, sitting as an arbitrator and construing the principles of both justice and equity, has established so firm a line of precedent that, so far as the plan proposed is concerned, New York can have no fear as to the outcome.

8. The Supreme Court of the United States has clearly intimated that, with respect to any interstate matter and before the Court should take cognizance thereof, ". . . . the case should be of serious magnitude, clearly and fully proved and the principle to be applied should be one which the Court is prepared deliberately to maintain against all considerations on the other side . . . ." (Missouri v. Illinois 200 U. S. 496).

Under the plan proposed, neither New Jersey nor Pennsylvania will be able to prove that the taking of these flood waters is either of serious magnitude or that any damage will accrue by reason thereof. New York should be prepared to admit that each of the three states has the right to use a portion of the water of the Delaware river. And when it is noted that the waters which are proposed to be taken are only a part of the share to which New York is reasonably entitled, it would seem that no action which either of the other states can bring could stop New York from using that herein sought.

9. It may be said by some that New York should not, in so important a matter as her water supply, embark on an enterprise which involves the exercise of rights as to which doubts may be raised. The answer to this contention naturally is that the proposed exercise of these rights does not go beyond a conservative and reasonable point; that the rights of New York are not inferior to those of the other states; that New York is constrained to insist on

them as both fair and evident; that the only tribunal empowered to determine the questions involved, if they be ever raised, is the United States Supreme Court; and that to this court New York, if need be, is ready and willing to submit her case, not alone because of her own needs and public requirements, but also because of the great importance which the utilization of interstate waters is certain to have on the development and growth of our country as a nation. Finally, and of great moment in any consideration of this question, is the fact that the plan proposed for developing these flood waters seeks to apply them to domestic and municipal use, which is the highest and most important use known.

The recommendations are predicated on the reasons which have been presented. The urgent need of proceeding on a program for a new supply of water was set forth in the report of October 9, 1926. The present supplies of water will serve to meet the requirements of the city until 1935. Only eight years remain in which to carry through the great works which must be completed before new water can be delivered. The importance and urgency of the situation is thus emphasized.

The following specific recommendations were, therefore, presented:

First: That the Board of Estimate and Apportionment return, without approval, to the Board of Water Supply, the map and plan dated September 13, 1926, which was transmitted with the report dated October 9, 1926.

Second: That the Board of Estimate and Apportionment, under the provisions of Section 3 of Chapter 724 of the Laws of 1905, as amended, approve and adopt the map and plan dated June 21, 1927.

Third: That, upon the approval of the plan, the Mayor, on behalf of The City of New York, make application, under the provisions of Section 522 of the Conservation Law, by petition, in writing, to the Water Power and Control Commission, for the approval of the said map, plan and profile of the proposed new sources of water supply.

Fourth: That steps be taken to secure suitable amendment of Chapter 724 of the Laws of 1905, so as to render the provisions thereof in all respects applicable to the contemplated operations in Delaware, Sullivan and Ulster counties.

Fifth: That, upon the approval of the map and plan dated June 21, 1927, and upon the making of petition to the Water Power and Control Commission, the Mayor, for and in the name of, the City of New York, do, in writing, advise the Governors of the states of New Jersey and Pennsylvania of the said approval and of the petition then being presented to the Water Power and Control Commission of the State of New York.

RECONSTRUCTION OF INADEQUATE WATER DISTRIBUTION SYSTEMS[1]

By Charles E. DeLeuw[2]

During recent years the writer has had occasion to report on the water works in a number of municipalities where existing water distribution systems were inadequate for the needs of the community. In a number of cities the distribution system was designed and constructed a generation or more ago. The original design may have been adequate for the needs of the municipality at the time of construction, but, judging from the existing conditions in several instances, it is obvious that no provision was made for growth either in population or area.

For various reasons the standards achieved in the early design of many water distribution systems fall short of present day requirements. The density of population and the concentration of urban development in our cities undoubtedly was less than at present. The capacity of old water mains has been greatly reduced in many instances by encrustation.

It is frequently found that the original gridiron was properly designed. However, additions to the original system have been constructed from time to time with but little, if any, thought given to the effect upon the distribution system as a whole. The result is a deficiency in cross connections and a surplus of dead ends. These factors, or some of them, have been the cause of partial break down of distribution systems in a number of Illinois municipalities. In two places the distribution system was found to be not only entirely inadequate for fire protection, but also for domestic requirements.

PRESENT DAY REQUIREMENTS

The National Board of Fire Underwriters has performed a very useful service in clearly setting down the fire protection requirements of the several parts of the water works system. The standards

[1] Presented before the Illinois Section meeting, January 28, 1927.

[2] Of Kelker, De Leuw and Company, Consulting Engineers, Chicago, Ill.

which have been established by it and which are generally accepted by water works engineers are particularly clear with respect to the water distribution system. These standards, established after years of thought and experience, show a gradual revision upwards, particularly as regards capacity of the distribution system and number of fire streams to be concentrated in given areas. For this reason, a distribution system which has been in place for twenty years or more seldom meets all of the requirements of the Board of Underwriters.

DESIGN

The municipality which has outgrown its distribution system is faced with heavy expenditures, if the entire system is to be rebuilt. Other underground and surface structures are in place and the cost of the work is increased by the necessity for cutting the existing pavements, sidewalks and other structures and their replacement. Such work is usually located in a built-up urban area, requires the use of hand labor almost exclusively and therefore introduces an added element of cost. There is an inconvenience factor also in the tearing up of streets, which, while not reflected in the cost of the work, does affect the convenience of the people residing in the community. This factor may assume large proportions in the eyes of the average citizen. The designer, therefore, must prepare a plan which will involve the least cost and inconvenience. A complete design of a new distribution system should always be made. As a matter of policy, however, the first construction may be limited to the arterial water mains branching out from the pumping plant and connecting and articulating the existing gridiron. If the existing system is deficient in cross connections or if it has a large number of dead ends, opportunity can be taken to remedy such deficiencies coincident with the installation of arterial mains.

At the intersection of arterial mains with existing mains, gate valves should be installed of such diameter as will conform to the size of the main to be installed in the complete new system. Where the existing main is of smaller diameter than that shown in the final design, reducers can be used pending the installation of the new main. This permits the smaller mains in the gridiron to be replaced at some subsequent date with a minimum of inconvenience and cost.

FINANCING IN THE STATE OF ILLINOIS

The large cost of a system of arterial water mains generally gives rise to a financial problem of serious proportions. There are in general three means available for financing municipal water works improvements in the State of Illinois. They are as follows:

a. Use of the waterworks fund or general funds of the municipality, including the use of general obligation bonds of the community. This is an excellent way of financing any municipal improvement, but ordinarily it is out of the question because the average Illinois municipality has bonds outstanding almost up to its authorized bonding limit. Moreover, in many cases, the entire bonding limit of the city would be insufficient to finance an arterial water main improvement.

b. Water certificates can be used for constructing waterworks and appurtenances. This class of security is fairly well known to most water works engineers. It is a certificate which is a lien on the plant (paid for out of the proceeds of the sale of water certificates) and on the earnings of such plant. The municipality stipulates in the agreement under which the certificate is issued that rates will be maintained so as to insure net revenue sufficient to provide for the interest and sinking fund requirements of the issue. Where an entirely new plant is being built it is possible that water certificates could be utilized both for the water supply pumping plant and water distribution system. However, it is the opinion of competent lawyers that water certificates cannot be issued to pay for the cost of a system of arterial water mains when constructed as a separate improvement.

c. The most practical way of financing water main construction is by special assessment under the Local Improvement Act. This procedure has been adopted in the three municipalities described below. One technical legal difficulty, however, which must be avoided is that of making the improvement a general improvement. Under existing statutes an improvement, to be a local improvement, must be one where various parcels of land in the municipality will receive an extra or special benefit over and above the general benefit received by the community as a whole. In order to avoid this legal technicality it is well either to omit a small portion of the municipality from the improvement district or to divide the municipality into two or more water districts.

Recently the writer has prepared plans for improvement of the existing systems in three Illinois municipalities: Riverside, Taylorville and Libertyville.

RIVERSIDE

Riverside is a village of approximately 5000 population, located ten miles west of the central business district of Chicago. It is a residential community and its outstanding characteristic is the novel

curving street lay out made by Frederick Law Olmstead at the time the village was developed, shortly after the Civil War. It is understood that the original distribution system consisted of wood pipe and that this was gradually replaced with cast iron pipe, so that in 1923 the major portion of thé village was covered with a gridiron of cast iron pipe, primarily of 4 inches in size.

The water supply of Riverside is from wells about 2,000 feet in depth penetrating Potsdam sandstone. The mineral content of the water is high. Deposits up to 1 inch in thickness have been found in the old mains, thus cutting the effective diameter of 4-inch mains to $2\frac{1}{2}$ inches, or in extreme cases to 2 inches. As a result of this there was almost no fire protection in the village, except in the immediate vicinity of the pumping plant. At peak hours of consumption the capacity of the distribution system was such that it was impossible to get water above the basement in many parts of the village. Such a situation was intolerable and brought forth an urgent demand that the situation be remedied.

The unique street lay out of Riverside lends itself readily to the construction of arterial water mains, so that such arterial mains were constructed varying from 8 to 16 inches in size, with additional 8-inch mains eventually to be constructed in those streets destined to become business streets at some future time.

In the levying of the assessment for the construction of arterial water mains it was assumed that all of the existing 4-inch water mains would be replaced eventually by 6-inch mains. It was reasoned, therefore, that property abutting on the streets where new arterial mains were to be constructed would receive an additional benefit over and above the general benefit to the other lands in the water district approximately equal to the cost of a 6-inch main. The policy of disconnecting existing services to houses from existing small mains and connecting to the new large mains was adopted. In order to make the improvement complete, it was also determined that new services should be installed, connected to the new mains, for all of the lots abutting on the improvement, so as to remove the necessity for again destroying the pavement at any future date. In spreading the assessment, therefore, the commissioner first computed the cost of the water services, charged them directly against the property served, then computed the cost of 6-inch mains in front of the various parcels of property abutting on the streets improved and deducted the total which could be spread in that manner from the total cost

of the improvement. The balance was spread against the entire water district. The cost of the improvement to a lot fronting directly on the new water main averaged about $2.30 per front foot of property and the cost of the improvement to the lots indirectly benefited amounted to approximately 30 cents per front foot of property.

The improvement was constructed in the year 1925 and resulted in immediate relief of the situation. Since that time no difficulty has been experienced with domestic pressure, and except for certain dead areas somewhat remote from the new arterial mains, the fire protection afforded by the new system is adequate. It seems likely, therefore, that the time for replacing the existing 4-inch mains will be indefinitely delayed.

TAYLORVILLE

The situation in Taylorville in 1926 was somewhat similar to that described in Riverside. Taylorville is a city of approximately 8000, the county seat of Christian County, and has a rectangular street lay out. Taylorville has its water supply in shallow wells and the water has a rather high mineral content. The use of this water has caused incrustation, but not to the same extent as at Riverside. The capacity of the existing water distribution system at Taylorville, however, is far below that required to give even reasonably good service. Some 98 per cent of the existing water main is but 4 inches in internal diameter and almost 50 per cent of this is on dead ends. For this reason the situation is almost as acute as that existing in Riverside in 1923.

The working pressure at the pumping plant is maintained at about 80 pounds per square inch and notwithstanding this pressure the effective pressure at houses during peak hours of the summer months is far from satisfactory. This is clearly evidenced by tests made in June, 1926. Tests were made of pressures at various hydrants with the hydrant closed and with no nearby hydrant open. Subsequent tests were made with the nearest hydrant open. The results set forth in table 1 indicate clearly the inadequacy of the existing 4-inch grid to provide the necessary flow.

Taylorville represents an average central Illinois community which is the center of a large farming area and which also has a moderate industrial development. It is a city which has had a consistent growth and which will no doubt enjoy a healthy growth in the

TABLE 1

Taylorville Water Distribution System—summary of pressure tests—June 23, 1926. Average pressure at pumping station, 78 pounds per square inch

Pressure at hydrant "A"—normal water demand

	LOCATION OF HYDRANT "A"	TIME	POUNDS PER SQUARE INCH
1	N. E. Corner of Square	10:45	46
2	N. W. Corner of Square	10:50	47
3	S. W. Corner of Square	11:08	47
4	S. E. Corner of Square	11:20	48
5	Elm and Snodgrass	11:35	52
6	Elm and Cherokee	11:48	55
7	Poplar and PawPaw	1:12	60
8	Poplar and Cheyenne	1:24	57
9	Poplar and Washington	1:45	45
10	Poplar and Cheney	1:53	45
11	Poplar and Mortan	1:58	46
12	Adams and Cheney	2:06	48
13	Market and Harrison	2:13	45
14	Adams and Washington	2:28	37
15	Cherokee and Franklin	2:34	63
16	Adams and East End	2:45	56
17	Wyandotte and Palmer	2:50	46
18	First and Shumway	3:12	47
19	Rich and Cheney	3:22	46
20	Market and Walnut	3:33	72
21	Palmer and Washington	3:00	46

Pressure at hydrant "A"—hydrant "B" open

LINE	LOCATION OF HYDRANT "B"	POUNDS PER SQUARE INCH
1	City Hall	15
2	N. E. Corner of Square	16
3	Alley one-half Block South	12
4	Alley one-half Block South	17
5	Elm and Long	6
6	Cherokee and Esther	8
7	Poplar and Chestnut	6
8	Poplar and Utah	21
9	Poplar and Clay	15
10	Poplar and Morton	15

TABLE 1—*Continued*

LINE	LOCATION OF HYDRANT "B"	POUNDS PER SQUARE INCH
11	Poplar and Cheney	12
12	Adams and Powers	5
13	Market and Morton	7
14	Adams and Madison	17
15	Adams and Wyandotte	43
16	Adams and Moore	4
17	Wyandotte and First	16
18	Rich and Morton	8
19	Rich and Houston	8
20	Market and Pawnee	44
21	600 feet North of Palmer	6

future. On the other hand, it is not developing at such a pace as will permit the construction of large mains in new subdivisions in outlying territory which would relieve the situation.

Arterial water mains have been planned for relief and it is proposed to construct these mains by special assessment and in two improvements. Taylorville is somewhat unique in that there is considerable built-up urban area which must be taken into account in any design, but which cannot be assessed due to the fact that it is outside the municipal boundaries. It would seem somewhat unfair to assess property within the existing city limits for an improvement which must be designed to provide for territory now outside the city. However, this seeming unfairness can be eliminated at the time that these subdivisions come into the city or when the property within them makes a connection to city water. At that time a charge can be made for the connection which will serve to equalize the burden on all of the property served.

After the construction of the proposed arterial mains, with the existing 4-inch mains, there will be a fairly satisfactory grid, which should be reasonably adequate for some time. While it is certain that the existing 4-inch mains will be replaced at some date in the future, it is thought that such construction will likely be postponed so long that it would be unfair to take that into consideration in connection with the assessing of the cost of this improvement. It has been determined, therefore, that the cost of the improvement shall be borne equally by all of the lots and parcels of land in the water

district, except in the case where a new arterial main will be constructed in a street where there is no water main at the present time, in which event the property will be charged an amount over and above the general assessment equal to the cost of a 6-inch water main.

For various reasons it was decided not to alter the service pipes in connection with the arterial water main construction and for that reason all of the existing 4-inch water main pipes will be kept in service. This has necessitated a number of rather awkward and perhaps unnecessary connections. It will be the policy of the city, however, to require connections to be made to the new mains at some time in the near future, at which time the 4-inch mains paralleling the new arterial mains can be put out of service.

LIBERTYVILLE

Libertyville is a village of about 3000 population, located near the center of Lake County. Libertyville is a rapidly growing residential surburban community somewhat like Riverside, but unlike Riverside it is a community which is expanding in area as well as in population. Libertyville has had a very rapid and vigorous growth in the last few years and is fairly typical of the suburban communities in the Chicago district, many new subdivisions having been made on the outskirts of the older and closely built-up portion of the village.

The water supply of Libertyville is from shallow wells and the quality of water is such that no serious incrustation has taken place. The gridiron of mains existing in 1925 consisted largely of 6-inch mains adequate to supply the population of a small village of one or two thousand which was the population at the time the majority of the mains were constructed. About two years ago some 1,600 acres of adjacent territory were annexed to the village and in the last two years it has been built up rapidly. This has permitted the development of portions of an arterial water main system in connection with construction of water mains for new subdivisions. It is expected that in this way a distribution system will be completed ultimately adequate to supply the needs of the enlarged community.

A small amount of 10- and 12-inch diameter water mains has been constructed in the southerly part of the village in accordance with a general plan for future arterial mains. The work has been financed by special assessment and ordinarily the water district included within any given improvement has been rather small. The subdivision being served by any particular improvement has been obliged to

assume its share of the cost of the arterial mains and any cost over and above that cost, which could not be fairly charged to the water district, has been assessed as public benefit. This system of financing which has been established in Libertyville is perhaps as painless and satisfactory as any which could be devised. It will, however, require several years for final completion.

DISCUSSION

G. C. Habermeyer: Chemical reactions of water from two wells probably cause the deposits which are found in pumps, meters and mains.

H. Ringness: Where a main is laid in a street in which there is an old main, why not leave both mains in?

Chas. E. De Leuw: They were left in place in Riverside, although leakage would be reduced if old mains were abandoned. Service connections with the new mains give much better pressures than if made with the old mains.

J. J. Woltmann: Where assessments are made and payments are to be made by districts to be served later, how can funds be collected from such districts and paid back to property owners who have paid for the improvements?

Chas. E. De Leuw: Theoretically, a city can exact payment from a territory to be connected and could pay the money into special assessment funds, but actually it is not likely to be done.

THE NEW FILTER PLANT AT FORT COLLINS, COLORADO[1]

By Wynkoop Kiersted[2]

A description of the old plant of the Fort Collins water supply works will not, in all probability, be a matter of interest further than the general statement that it consisted of a series of negative head mechanical filters with a clear water basin beneath them, an adjoining coagulating basin, a small basin in which coagulants are applied, and a basin of a capacity of about two million gallons, primarily designed for storage purposes to tide over intervals of high river turbidity. The water from both the old and the new plant flows by gravity to distant distributing reservoirs, thence into the distributing system of the city under sufficient pressure for general service. The new water purification plant adjoins the old one and is so designed as to utilize as far as possible the old plant. The new plant consists of six mechanical filters in sets of three on each side of a pipe gallery, all under cover of a fireproof building. The head works from which a water supply is taken remains as originally designed and constructed. A 36-inch creosoted wood stave pipe was constructed to connect the head works with the storage reservoir. This pipe line supersedes a 20-inch line originally constructed to convey water from the head works to the old filter plant.

The storage reservoir, now settling basins, was completely remodeled. This basin is about 300 feet long and 100 feet wide. A reinforced concrete division wall was constructed across the basin dividing it into two basins, the smaller of which is of a capacity about one-quarter the total capacity of the basin. The bottom of the small basin was excavated hopper-shaped, floored with concrete and supplied with an independent drain pipe to the river. The small basin receives the raw water and is intended to afford a short period of sedimentation for the heavy sandy sediment carried by the river in freshets. A chemical house was constructed at the south end of the

[1] Presented before the Rocky Mountain Section meeting, February 8, 1927.

[2] Consulting Engineer, Kansas City, Mo.

division wall of this basin. In this house are located four coagulating dry feed machines, two for the application of hydrated lime and two for the application of alum or such other coagulant as may be used. These machines deposit the dry coagulant into the water entering the basement of the chemical house after sedimentation in the small division of the settling basin. After receiving the chemicals the water flows through different compartments in the basement of the chemical house and finally reaches the outlet pipe laid across the basin parallel with the division wall. Openings are made in this pipe of a size and so spaced as to give a substantially uniform distribution of the treated water the entire width of the larger of the two divisions of the basin. The treated water deposits coagulated sediment while flowing over 200 feet to the outlet where the water passes over a weir into the outlet chamber. From this chamber the water flows to both the old and the new filters through pipe lines, the larger of which is 30 inches in diameter. Both of the settling basins have concrete bottoms and are concrete lined. By-pass pipes are provided by which either basin can be emptied for cleaning without interfering with the operation of the works. These by-pass pipes are 36 inches in diameter of reinforced concrete.

The only novel feature about the settling basin is the adjustable weir gate over which the water from the small basin flows into the basement of the chemical house. This gate is made adjustable because the fluctuation of river level causes several feet variation in the operating level of the water in the settling basin. This weir gate is operated by a worm gear which permits the adjustment of the lip of the weir to any desirable level within the range of water level fluctuation.

The six filter units of the new filter plant were built independently of reinforced concrete, that is, there is no concrete bond between the units of the filter plant above the floor slab. Each filter unit has an area of 280 square feet and a rated filtering capacity of one million gallons daily, equivalent to a rate of $2\frac{1}{2}$ gallons per square foot per minute.

The manifold of each filter consists of a cast iron header 12 inches in diameter laid beneath the floor of the filter and cased in concrete, to which lateral pipes are bolted spaced 10 inches apart, of $2\frac{1}{2}$-inch Byers wrought iron pipe. Each lateral is perforated on the bottom with a row of $\frac{7}{16}$-inch holes spaced 6 inches apart. These holes, totaling 624 for each filter, admit filtered water into the manifold and

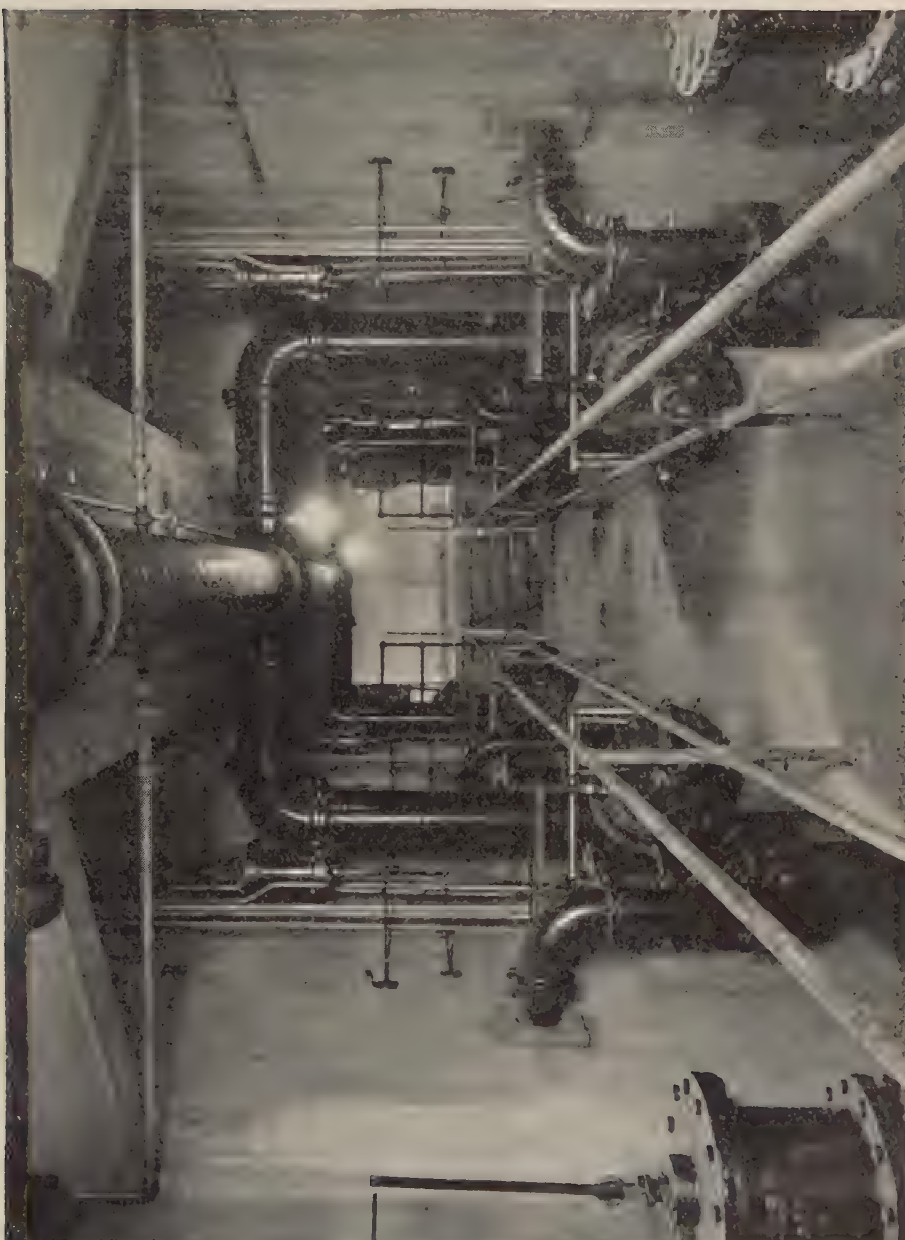

Fig. 1. Pipe Gallery, Fort Collins Filtration Plant

thence through the header into the outlet flume in the pipe gallery. They also admit water under the filter sand by reverse flow in washing the filter. These lateral pipes of the manifold are surrounded with 15 inches of graded gravel. On the top of the gravel is 30 inches of graded filter sand. The filter sand is bank sand obtained from a locality near Fort Collins, screened to conform to the usual specification for filter sand.

The pipe gallery is 12 feet wide with the level of the floor $5\frac{1}{2}$ feet below the level of the bottom of the filter tanks. On the floor of the pipe gallery is a reinforced concrete flume with opening 4 feet square which receives the water from each of the six filter units. This flume is located centrally in the gallery and affords a clear passageway from end to end of the gallery. At the outlet end of the flume is a weir with overflow area above the weir for 12 filter units. Back of this weir is a pipe communicating with a still box and in the still box is a float actuating a recording device registering the depth of water over the weir to within $\frac{1}{16}$ inch and is susceptible of reading to one-half this amount.

Immediately above the flume, and with a clearance of 8 feet 9 inches between them, is the concrete inlet flume which admits water to the filters. This flume is of reinforced concrete with opening 3 feet wide, 3 feet 3 inches high, supported on concrete brackets molded monolithic with the filter tanks. An 8-inch pipe connects the inlet flume with each of the filters. This pipe has an elbow and 8-inch flanged nipple with the face of flange set level. To the face of this flange is bolted the monel metal orifice above described which controls the rate of flow into the filter under a uniform head of 6 inches; in other words, the level of the water in the inlet flume is 6 inches above the orifice plate.

Under the inlet flume a 12-inch wash water pipe is suspended and connected with a 12-inch branch pipe leading to the header of each of the filter units. The capacity of this pipe is sufficient for a discharge of wash water which will cause a rise in the filtered tub of at least 2 feet per minute. At this rate of rise the flow of water for washing purposes is 5250 gallons per minute equivalent to $7\frac{1}{2}$ million gallons per day. In other words, the rate of flow during the washing inverval is $7\frac{1}{2}$ times the normal filtering rate of each unit.

The wash water after passing upward through the sand is received in three cast iron lateral wash troughs, 20 feet long, spaced 4 feet 8 inches apart center to center and one-half this distance from the

side walls of the filter unit. The water from these lateral troughs is received into a main wash trough at the end of each filter unit next to the pipe gallery. From the main trough the water passes through a 16-inch drain valve into a 20-inch drain pipe leading to the river. The drain valve is what is known as a plug valve set flush with the bottom of the main wash trough. It is manipulated from the filter house floor level through a bevel geared valve stand.

In addition to the plug drain valve there are four other valves on each filter unit marked "Influent," "Effluent," "Wash," and "Rewash." All of these valves are hydraulically operated from an operating table set on the floor of the filter house. The water pressure for operating these valves is derived from a wash water tank constructed in earth excavation about 50 feet above the level of the filter room floor. This tank is a part of the original works and is of about 180,000 gallons capacity. A simple mechanism connecting each hydraulic valve with the operating table indicates the position and direction of motion of each valve. All of the hydraulic valves are in the pipe gallery between the outlet flume and the side walls of the filter, so adjusted and located as to be accessible from the top of the outlet flume. On the 8-inch outlet branch from the header of the manifold is placed the monel metal effluent control orifice between two conveniently located flanges of the effluent branch.

There is one departure from ordinary practice in the valve layout which perhaps is worthy of notice. The 6-inch rewash pipe discharges into the main wash water trough of each filter. Ordinarily this valve is made to discharge into the filter drain pipe. In the Ft. Collins case it is much more convenient to connect it directly with the main wash trough. The utility of this rewash pipe is doubtful. Its purpose is to waste filtered water from a filter immediately after washing for a period of 5 to 15 minutes, as the case may be, until the filter settles down to normal working conditions. This pipe and its connections could be entirely abandoned without affecting the efficiency of the filter, provided the operator is careful to let each filter unit stand until the coagulant and sediment remaining in the water after washing has settled upon the sand and then to bring the filter slowly up to its normal rating. Perhaps a period of half an hour might be required for this purpose. The rewash connection is therefore more of a safety device than a necessity.

The water from the outlet flume discharges over a weir into a chamber deep enough to receive water from the clear water basin

of the old filters. After the effluent of the two filter plants unite in this chamber the water flows over a second weir into an outlet chamber. A pipe connection on the upstream side of this second weir connects with a still well in which is a float actuating a recorder of the same size and character as that above described. In the outlet chamber the water enters a 30-inch gravity main leading to a distributing reservoir several miles distant. There is also a pipe connecting the outlet chamber with a third still well wherein the float operates an indicating gauge to indicate the level of the water at the outlet.

Each of these several outlet chambers extends 6 feet or more below low water level in the adjoining river. This is necessary owing to the deep excavation required for the pipe from clear water basin of the old filters. These filters are constructed with the tops of the filter tanks at ground level. The tops of the new filter tanks are 3 or 4 feet above the natural ground level. This deep construction providing for a connection to the old filter plant, has added considerably to the cost chargeable to the new plant.

A balcony is constructed around each filter unit on the same level as the floor which covers the pipe gallery. The pipe gallery is reasonably well lighted and thoroughly ventilated by openings in the floor over the gallery covered with metal subway grating.

The entire filter plant is housed in a brick building with steel windows and doors and roof girders. The roof is of Federal cement tile covered with 5 ply Barrett roof graveled. The trim of the building is of Bedford cut stone. The building is heated by a forced draft hot air furnace. The heated air penetrates all parts of the building, even into the pipe gallery through the grated openings above described and is drawn out through a duct in the pumping room basement.

The outlet chambers above described are covered with a heavy reinforced concrete floor, one flight of stairs below the level of the main filter room floor. This basement contains two motor driven filter wash water pumps and a turbine water wheel for keeping the wash water reservoir supplied with water. In the opposite end of the pump room basement is a chlorinator of the Wallace-Tiernan vacuum type which supplies liquid chlorine to the water as it passes into the outlet pipe leading to the distributing reservoir. Electricity is derived from a 110-volt Exide battery of 56 cells for light and power purposes. The water wheel is supplied with water through a 30-inch pipe about 2000 feet long.

The water from the settling basin enters the filter inlet flume through an inlet well on the outside of and adjoining the new filter building. A butterfly valve actuated by a worm gear is connected with the 30-inch inlet pipe inside the inlet well. The gear has an extension shaft passing through a sleeve to the inside of the filter house, by which the valve gate can be set at any angle. This valve enables the attendant to control the volume of incoming water and thereby to control the level of the water in the inlet flume. There is an overflow waste weir in the inlet well to prevent flooding of the filters.

The new filter plant is located about 15 feet south of the old filter plant. This space between the two plants has been constructed into a furnace cellar, coal storage room, and a bricked-in inclosure for the force draft fan and motor. The roof over the furnace basement is of reinforced concrete. A wing from the new filter building extends to a junction with the old filter building and affords a well lighted and convenient work room for the attendant over the furnace basement. The stairway leading into the furnace basement forms a vent for the warm air ascending from around the furnace sufficient to heat the work room. Toilet fixtures are also located in the wing of the building and connected with a sewer leading to a septic tank.

The cost of the filter plant was \$135,972, equivalent to \$22,662 per million gallons filtering capacity. Several factors contributed in an unusual degree to the cost of this plant, namely, deep excavation because of the union of the effluent from the old and the new filter plants and because of the small fall between the head works and the new plant; provision in the capacity of both the influent and effluent flumes for six additional filters; the use of a 16-inch wash water pipe part of the way in order to reinforce the washing facilities of the old filters as well as to furnish wash water for the new filters and any future extension of the new filter plant. Through the united effort of Mr. Lawver, City Engineer, and his assistants, Mr. Connell Resident Engineer and Messrs. Spotts & Malcom, Contractors, the construction work is a credit to all concerned. There is no record of operating costs as the filters are not yet in commission awaiting the completion of the pipe line connecting the new filters with the distributing reservoir.

PROTECTION OF WATER SERVICES IN EXPOSED LOCATIONS[1]

By S. D. Bleich[2]

It is in connection with the ventilation of the subway railroads in New York City that it became necessary in a number of instances to lay water services exposed to the atmosphere through the ventilating chambers. This resulted in studies and investigations to determine how such services should be insulated so that they may be as well protected against freezing as if they were normally laid in the ground.

The ventilation of the subway railroad is effected by arranging sufficient area of openings on the sidewalks at the curbs which lead into the subway through ventilating chambers. These openings are covered with steel gratings. The steel gratings are usually 4 feet wide and for a four-track subway occupy on each side of the street a length of approximately one-third the length of the railroad. The water mains are usually laid over the roof within the roadway except in rare cases where the pipes are too large for the available cover over the roof of the subway structure. In such cases the pipes are laid under the sidewalk between the subway structure and the building line.

Every effort is made to keep water and other services outside and independent of the subway structure. Where the water mains are under the sidewalk and adjacent to the subway, these services can be connected to the mains without carrying them through the subway ventilating chambers. But where the mains are located under the roadway, which is the usual case, interference frequently results between the ventilating chambers and the house services. The alternative arrangements have been used to avoid carrying the services through the subway structure. These are in the order of frequency in which they are used, as follows:

1. The length of the subway ventilators is split up by omitting one

[1] Presented before the Chicago Convention, June 10, 1927.

[2] Board of Transportation, New York, N. Y.

or two 5-foot bays of gratings at alternate lot lines through which the services of the two adjoining buildings are carried to the mains in the roadway. The surrounding earth and the concrete walls of the ventilators furnish the necessary insulation against freezing around the water services (see sketch *a* of figure 1).

2. The second method is to provide under the sidewalk between the ventilating chamber and the building line an auxiliary 4- or 6-inch water pipe in addition to the main in the roadway. The services

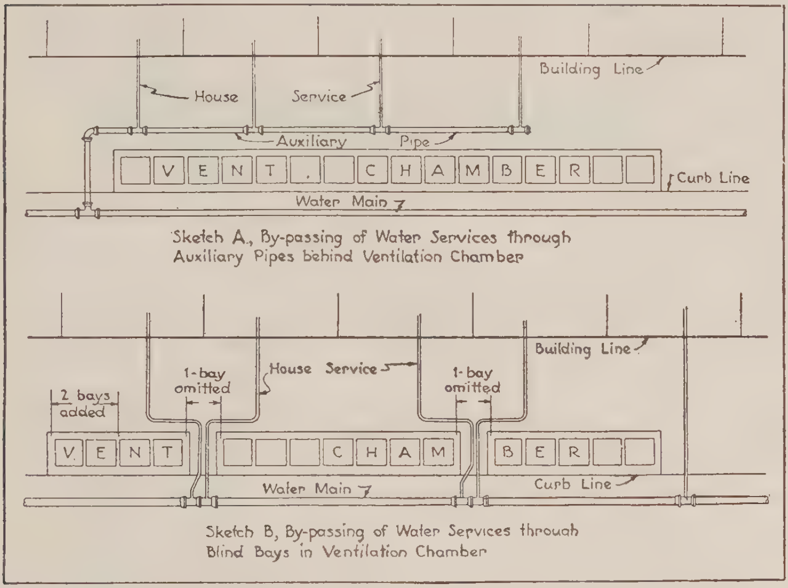

FIG. 1. METHODS OF PROVIDING PROTECTION AGAINST FREEZING OF SERVICES, WITHOUT AUXILIARY INSULATION

are then connected to the auxiliary pipe directly, thus the services are surrounded with the normal amount of earth protection. This method is not frequently used, as it complicates the water distribution system.

Although every effort is made to avoid carrying services through the subway ventilating chambers, it sometimes proves unavoidable and the water services as well as electric and gas services have to be carried through the ventilators exposed to the atmosphere. It then becomes necessary to protect the exposed water service pipes from freezing.

Extensive theoretical and experimental work was done by the engineers of the Board of Transportation to develop a design which would adequately protect the water services against freezing when exposed to extreme low temperatures for such periods as may occur, as indicated by the records of the Weather Bureau.

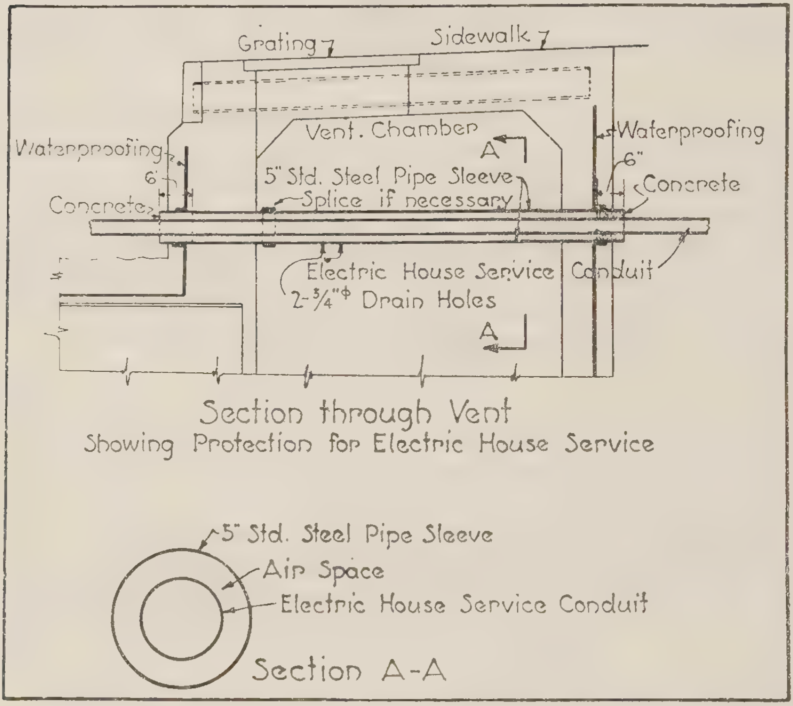

Fig. 2. Protection for Electric House Service Passing through Ventilating Chamber

Electric and gas services are usually carried in ferrules through ventilating chambers to protect them from injury and to facilitate replacement when necessary. This method is shown on figure 2.

Water services are usually $\frac{3}{4}$ to 1 inch in diameter and, if exposed to an outside temperature of 0° F., would freeze in less than three hours. If such services were carried in steel ferrules in the same manner as electric and gas services the air space and ferrules would only give an additional protection of about two hours against freezing.

This is insufficient, as atmospheric temperatures of 0° to minus 10°F. last frequently for much greater periods than five hours and water within the pipes is apt to remain unchanged overnight for homes and for two days (Sunday and one holiday) for business and industrial places.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Type	Insulation	Heat lost in Kgm Calor per Hour per Deg C	Time in Hours					
			Outside Temp 0°F - Init Temp Water 40°F			Outside Temp -10°F - Init. Temp Water 40°F		
			Water 40°F. to 32°F	Water 32°F. to Ice 32°F	Total	Water 40°F to 32°F	Water 32°F to Ice 32°F	Total
a	0.3 Waterproofing; 3-1" Layers Hairfelt; ¾" Φ Service Pipe	0.098	0.6	13.1	13.7	0.5	10.1	10.6
b	7" Pipe; 3-1" Layers Hairfelt; ¾" Φ Service Pipe	0.099	0.6	12.9	13.5	0.5	10.0	10.5
c	6 Pipe; 3½ Pipe; Air Space; ¾" Φ Service Pipe	0.180	0.3	7.1	7.4	0.3	5.4	5.7
d	7" Pipe; 3" Quartzsand; ¾" Φ Service Pipe	0.149	0.4	8.6	9.0	0.3	6.5	6.8
e	¼" Asphalt Paint; 3-1" Layers Hairfelt; 1½" Pipe (omitted for e'); Air Space; ¾" Service Pipe	0.0792	0.8	16.2	17.0	0.6	12.3	12.9
e'		0.098	0.6	13.1	13.7	0.5	10.1	10.6
f	9 [illegible]; [illegible] (omitted for f'); 3-1 [illegible] Hairfelt; Air Space; [illegible] Pipe	0.075	0.8	17.1	17.9	0.7	13.0	13.7
f'		0.092	0.7	14.0	14.7	0.6	10.6	11.2
g	[illegible] Pipe; [illegible] Space; [illegible] Service Pipe	0.43	1.0	21.0	22.0	0.8	16.0	16.8
h	5 Pipe; Air Space; 3 Service Pipe	0.575	1.7	35.6	37.3	1.4	27.3	28.7
k	6 Pipe; Air Space; 4 Service Pipe	0.723	2.5	50.0	52.5	2.0	38.4	40.4
l	¼" Asphalt Paint; 3-1" Layers Hairfelt; 2½" Ferrule (omit. for l'); Air Space; [illegible] Service Pipe	0.139	3.3	65.6	68.9	2.5	50.0	52.5
l'		0.148	3.0	61.0	64.0	2.4	47.6	50.0
m	¼" Asphalt Paint; 3-1" Layers Hairfelt; 3½" Ferrule (omit for m'); Air Space; 3" Service Pipe	0.172	5.9	117.8	123.7	4.6	91.2	95.8
m'		0.186	5.5	110.0	115.5	4.3	84.3	88.6
n	¼" Asphalt Paint; 3-1" Layers Hairfelt; Air Space; 4½" Ferrule (omit. for n'); 4" Service Pipe	0.204	8.9	178.5	137.4	7.0	136.5	143.5
n'		0.222	8.2	165.0	173.2	6.4	125.0	131.4

Fig. 3. Experimental Findings in Study of Insulation for Water Service Pipes against Freezing

Special insulation must be provided which will prevent the water within services from freezing for a period of at least forty-eight hours, when the outside temperature remains the lowest, which for New York City is about 10° below zero Fahrenheit and the initial temperature of the water is 40° F, which corresponds approximately to its maximum density.

The theoretical calculations were based on the standard formula giving the loss of heat through a circular ring one unit in length during a unit of time of one hour for a difference in temperature of 1°C. when surrounded with one or more layers of insulating material. It was found convenient to use the metric system. The initial temperature of the water was taken at 40°F. or 4.4°C. The atmospheric temperature was taken in one set of calculations at 0°F. and in a second set of calculations an atmospheric temperature of −10°F. was used. For details of the calculations see figure 3.

The insulation serves to retard the transmission of heat from the water within the pipe to the outside atmosphere which is at a lower temperature. The effectiveness of the insulation is indicated by the low figure for the loss of heat given in column 3 of figure 3. The lower this figure the better the insulation. The figures in column 3 represent the loss of heat in one hour from the water within the pipe to the outside air in kilogram-calories for 1°C. difference in temperature between the water and atmosphere for a length of pipe of one meter. At the initial time, when the water in the pipe becomes at rest, we have the maximum difference in temperature between the water and the outside air and, therefore, the greatest rate of heat loss from the still water. As the temperature of the water falls, due to loss of heat, the difference in temperature becomes less and the rate of heat loss becomes correspondingly reduced, with the result that the time it takes for the water to drop from an initial difference in temperature T_2 to a difference in temperature T_1 in degrees Centigrade is represented by a logarithmic equation:

$$t_1 = \frac{q}{k} \text{ nap. log } \frac{T_2}{T_1} = \frac{q}{k} \, 2.3026 \log \frac{T_2}{T_1}$$

in which *nap. log* represents the Napierian logarithm and *log* represents Briggs logarithm; t_1 gives the time in hours; q is the quantity of water in kilograms in a meter length of pipe; and k is the loss of heat in kilogram-calories per hour for the type of insulation considered for a meter length of pipe for 1°C. difference in temperature, as given in column 3 of figure 3.

This process of falling temperature continues until the water within the pipe becomes 0°C., when freezing begins. The time for the temperature of the water to fall from 4.4° to 0°C. is computed by the logarithmic formula just given and the results are recorded in column 4 for the various types of insulations for an outside temperature of 0°F., and in column 7 for an outside temperature of −10°F.

TABLE 1

Experimental results of freezing time for various insulations on 1-inch lead pipe

TEST NUMBER	INSULATION	TEMPERATURE: Initial water	TEMPERATURE: Outside	TIME: To 32° water	TIME: 32° water to 32° ice	TIME: Total
		°F.	°F.	hours	hours	hours
1	No insulation	40	6.5	0.5	3.0	3.5
			0	—	—	2.8
2	1-inch hairfelt, $\frac{1}{4}$-inch air space, 4-inch wrought iron pipe	40	8.5	1.0	9.0	10.0
			0	—	—	7.3
3	3-inch hairfelt	40	2.0	2.0	7.5	9.5
			0	—	—	8.9
4	3-inch Flaxlinum (coarse flax fibre)	40	8.5	2.0	11.0	13.0
			0	—	—	9.5
5	3-inch Armorak (alternate layers $\frac{1}{2}$-inch hairfelt and tar paper)	40	2.5	2.5	9.0	11.5
			0	—	—	10.6
6	1-inch hairfelt, $\frac{1}{4}$-inch air space, 4-inch wrought iron pipe, 3-inch Armorak	40	2.0	5.0	10.0	15.0
			0	—	—	14.1
7	4-inch Armorak	40	4.0	5.0	12.0	17.0
			0	—	—	14.9
8	1-inch hairfelt, $\frac{1}{4}$-inch air space, 4-inch wrought iron pipe, 4-inch Armorak	40	3.5	5.5	21.5	27.0
			0	—	—	24.0
9	3-inch woolfelt covering, 2 plies rubberoid roofing	40	4.0	2.5	12.5	15.0
			0	—	—	14.1
10	1-inch hairfelt, $\frac{1}{4}$-inch air space, 4-inch wrought iron pipe, 3-inch woolfelt	40	4.0	4.0	14.0	18.0
			0	—	—	15.8
11	1-inch hairfelt, $\frac{1}{4}$-inch air space, 4-inch wrought iron pipe, $2\frac{3}{4}$-inch tar paper	40	3.0	4.5	9.0	13.5
			0	—	—	12.2
12	1-inch hairfelt, $\frac{1}{4}$-inch air space, 4-inch wrought iron pipe, 1-inch woolfelt; 1-inch hairfelt, 1-inch tar paper	40	6.0	5.5	7.5	13.0
			0	—	—	10.6
13	3-inch 85 per cent magnesia covering, 3 plies rubber roofing	40	3.5	2.0	6.0	8.0
			0	—	—	7.1

TABLE 1—*Continued*

TEST NUMBER	INSULATION	TEMPERATURE: Initial water	TEMPERATURE: Outside	TIME: To 32° water	TIME: 32° water to 32° ice	TIME: Total
		°F.	°F.	hours	hours	hours
14	4-inch powdered cork, 1-inch board box	40	4.0	4.0	20.0	24.0
			0	—	—	21.0
15	3-inch cork mastic (granulated cork and asphalt) 1-inch board box	40	3.0	3.5	4.0	7.5
			0	—	—	6.8
16	1-inch hairfelt, ¼-inch air space, 4-inch wrought iron pipe; 3¼-inch Nonparial compressed cork	40	2.0	4.5	12.5	17.0
			0	—	—	16.0
17	3-inch pine sawdust, 1-inch board box	40	6.0	3.0	7.0	10.0
			0	—	—	8.1
18	1-inch hairfelt, 3½-inch wood (rectangular box)	40	4.0	3.5	13.0	16.5
			0	—	—	14.4
19	3¼-inch horse manure, 1-inch board box	40	3.5	4.0	18.0	22.0
			0	—	—	19.6

After the freezing temperature of the water is reached, the temperature of the water remains constant during the freezing or crystallization process during which the heat is lost from the water until all the water within the pipe is converted into ice. The time in hours required for freezing at the freezing temperature is:

$$t_2 = \frac{80q}{kT_1}$$

in which T is the temperature of the atmosphere below 0°C., and q and k are the same as in the formula given for t_1. 80 represents the latent heat of freezing. The results of t_2 are given in columns 5 and 8 of figure 3. The total time of freezing from the initial temperatures of water 4.4°C. (40°F.) is the sum of t_1 and t_2 and is given in columns 6 and 9 of figure 3.

The tests on various insulating materials on water services were

made in one of the refrigerating rooms of the Manhattan Refrigerating Company at No. 525 West Street, New York City.

The insulating materials and lead pipe were furnished by the Robert A. Keasby Company, gratis, at West and Bank Streets, New York City.

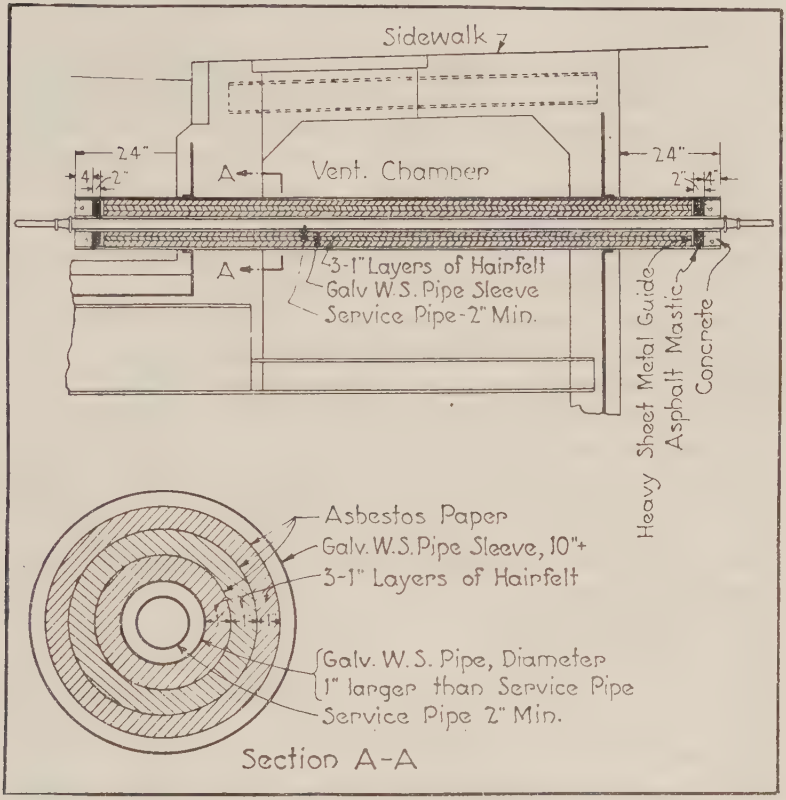

FIG. 4. METHOD OF INSULATION FOR WATER SERVICES CARRIED THROUGH VENTILATION CHAMBER

The lead pipe was 1 inch in diameter, and, to allow for expansion of the water during freezing, the pipe was only 0.8 filled. The initial temperature of the water was 4°C. (40°F.), which is a temperature of maximum water density.

The temperature of the refrigerating room varied at different times from 0° to 8.5°F.

Temperature readings of the water within the pipe were taken periodically, from which the time it took for the temperature of the water to fall to 32°F. without freezing was determined. These results are given in table 1 for the various insulating materials described.

Due to the fact that the pipe was not entirely filled with water, the times of freezing given in these tables should be increased by about 16 per cent.

An examination of these tests indicates clearly that, with a 1-inch pipe, it is practically impossible to secure adequate insulation for forty-eight hours, unless the insulating material is made very heavy, estimated about 12 inches or more for the best insulating material.

It appeared evident that more security against freezing would be gained by increasing the size of the service pipe to at least 2 inches, and insulated with 3 inches of hairfelt, than covering a $\frac{3}{4}$-inch or 1-inch pipe with excessive insulating material (see fig. 4).

We were unable to arrange for a test on a 2-inch pipe thus insulated.

Comparisons made, however, between theoretical calculations and actual tests on a 1-inch pipe agreed so closely that we had full confidence in the theoretical results obtained on computation for larger service pipes, as given in figure 1.

For two of the pipes tested the actual results were compared with those obtained by theory. They are as follows:

1. One-inch lead water pipe, insulated with 4-inch hair felt, in $\frac{1}{2}$-inch layers, alternated with tar paper.

Initial water temperature, 40°F.

Outside temperature, 4°F.

Actual time to freeze, 17 hours.

Adding 16 per cent actual time of freezing with the pipe full would be about 20 hours.

The computed time was found to be about 27 hours.

2. One-inch lead water pipe, insulated with 1-inch hair felt, $\frac{1}{4}$-inch air space.

Four-inch wrought iron pipe and 4-inches of hair felt, in $\frac{1}{2}$-inch layers, separated with tar paper.

Initial temperature of water, 40°F.

Outside temperature, 3.5°F.

Actual time to freeze, 27 hours, plus 16 per cent, equals 31.5 hours.

The theoretical time was found to be 29.9 hours.

The discrepancy between the actual and computed time may be due to a different hair felt having been used than that assumed in the computations, thereby giving a different constant of conductivity; also, the correction of 16 per cent made in the test is approximate only.

The type of insulation finally adopted for protecting water services against freezing when located in exposed places is shown on figure 4. The water service is increased to at least 2 inches in diameter carried through an insulated ferrule consisting of an inner galvanized steel pipe surrounded with three layers of 1-inch hairfelt separated by asbestos paper and the whole protected from injury with an outer galvanized steel pipe. This type of construction is extended at least 2 feet into the adjoining ground. The ends of the insulated ferrule are sealed with asphalt mastic and concrete.

COÖPERATIVE STATE CONTROL OF PHENOL WASTES ON THE OHIO RIVER WATERSHED[1]

By E. S. Tisdale[2]

Excessive rainfall on the watershed of the Ohio and Mississippi Rivers has at this time brought about the most disastrous floods in history of the valley of the Mississippi River. Loss of lives and destruction of property mounting into billions of dollars will focus the attention upon the need of flood prevention measures to forestall another such disaster.

On the Ohio River, a large tributary of the Mississippi, great damage to certain public water supplies was imminent five years ago, not from excessive floods, as is now the case on the Mississippi River, but on account of a new type of industrial waste pollution discharged in increasing amounts into streams on the Ohio River watershed. The phenol and tar acid wastes from by-product coke plants had a power of enormous penetration and in extraordinarily great dilution caused offensive tastes and odors in public water supplies taken from the streams into which these wastes were discharged.

In the State of Ohio alone in 1922 this new type of trade waste pollution bid fair to damage 40 per cent of the public water supplies and to affect detrimentally more than 50 public water supplies in the six states down stream. The purpose of this brief paper is threefold:

1. To indicate the magnitude and type of this industrial waste pollution which menaced public water supplies in Ohio, West Virginia and Pennsylvania.
2. To outline the methods taken to cope with them, namely, state coöperation with the adoption of a similar policy toward the industry.
3. To show the final result achieved, namely, practical elimination of phenol wastes from the Ohio River watershed and the birth of a new era in stream pollution control.

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[1] Presented before the Water Purification Division, Chicago Convention, June 10, 1927.

[2] Chief Engineer, State Department of Health, Charleston, W. Va.

THE TYPE AND MAGNITUDE OF PHENOL WASTES POLLUTION

The four splendid progress reports for the years 1923 to 1926 by the American Water Works Association Committee on Industrial Wastes in Relation to Water Supply, made by Chairman Almon L. Fales, set forth concisely and completely the growth and extent of industrial waste pollution in the United States. The relative importance which phenol wastes were assuming is indicated by the fact that one-third of the last report for the year 1926 was devoted to a discussion of phenol wastes and the difficulties met in public water supplies due to increasing prevalence of objectionable tastes occasioned by the rapid growth of the by-product coke industry. The nauseating, medicinal taste caused by this waste, even in minute quantities when combined with the chlorine used in water purification processes, was one of the outstanding characteristics of the problem.

H. R. Crohurst, sanitary engineer for the United States Public Health Service in 1924, who made a careful investigation of the extent of phenol pollution as a national question, estimated that 1 part of phenol waste to 75 or 100 million parts of chlorinated water was the common minimum dilution at which tastes and odors would be detected. Following his investigation he reported that 19 by-product coke plants were located on the highly industrialized upper Ohio River basin in West Virginia, Ohio and Pennsylvania discharging phenol bearing wastes into the river. He further showed that damage was then being caused to 34 public water supplies in five states down stream and 24 more water supplies might reasonably be expected to have trouble in the future. The pollution problems were common to several states and the phenol wastes had the power of causing objectionable tastes and odors even in minute quantities. This new type of pollution was due to expansion and growth in the by-product coke industry.

R. D. Leitch, chemical engineer for the United States Bureau of Mines, has indicated the magnitude of the by-product coke industry in a recent report. He states that, in 1923, 37 million tons of the 55 million net tons of coke were produced from by-product coke ovens. He estimated that 38 million tons of still wastes were produced annually and before the remedial work brought about by a state coöperation control program, about 75 per cent of these phenol-bearing wastes were discharged directly into the streams.

The remaining wastes were disposed of by coke quenching processes, the largest plants employing this method of treatment being located in Pennsylvania where the State Health Department had been actively working with the industries to prevent damage to public water supplies.

THE FIRST BEGINNINGS OF STATE COÖPERATION—PHENOL ELIMINATION ON THE OHIO WATERSHED

The underlying keynote in the method adopted to cope with control of phenol wastes was "interstate coöperation." Basic facts were first obtained by a careful study of the Sanitary Engineering Divisions in the three most affected states. All parties concerned were then called into the conference and a basic policy adopted. Careful investigation indicated that phenol wastes discharged into the Monongahela River in West Virginia were causing tastes in Pennsylvania's public water supplies derived from this river. Pennsylvania's by-product coke plants discharging tarry phenol wastes to the Ohio River in Pennsylvania were harming both Ohio and West Virginia public water supplies, along the Ohio below the Pennsylvania line and the Beaver River and its tributaries were grossly polluted by phenol wastes in Ohio before this stream entered Pennsylvania, where it is used for public water supply purposes. Public water supply intakes and phenol waste discharge outfalls are closely enmeshed on this highly industrialized watershed. Public health statesmanship and salesmanship of a high order were called for in coping with the problem and from the Ohio State Health Department came the initiative to unravel this public water supply and objectionable industrial waste tangle. We shall list consecutively the main steps leading up to the interstate agreement of 1924 between Ohio, Pennsylvania and West Virginia, which had as its main object, the elimination of phenol wastes from the Ohio River watershed.

First step

A dramatic phenol waste taste demonstration took place in 1922 when Cleveland's public water supply developed nauseating medicinal tastes so that it was unfit for drinking purposes due to pollution from by-product coke works on the Cuyahoga River. These wastes were carried by ice and wind currents out into Lake Erie 4½ miles to Cleveland's water supply intake. Dr. J. E. Monger,

Director of Health, and W. H. Dittoe, then Chief Engineer of the Ohio State Health Department, following this occurrence, took the initiative in thrashing out the question of taste producing wastes and their damaging effect upon public water supplies. At the request of the Ohio Department of Health, Surgeon General Cumming of the United States Public Health Service in May, 1923, called the first phenol conference at Washington, D. C., to take testimony in the case and evaluate the problem from a national standpoint. Fifteen State Health Departments and representatives from the United States Bureau of Mines, United States Bureau of Standards and United States Public Health Service were present at this first meeting.

Second step

June, 1923, one month later, witnessed a group meeting at Cleveland, Ohio, where executives of the by-product coke companies of this state met with the Ohio Health Department and agreed upon a policy to keep the phenol wastes out of the streams of Ohio. The by-product coke companies of Ohio here agreed to coöperate with the Ohio Health Department, either to keep the phenols out of the stream entirely by a closed system or by treatment to eliminate the phenols from the wastes discharged. The coke companies stated that in all fairness to them the same policy should also apply to by-product coke companies in neighboring states. To try and expand the scope of the policy adopted between industry and the Ohio Health Department was the purpose of the following conference at Washington, D. C.

Third step

A group of interested states met in Washington at a conference called by Surgeon General Cumming in January, 1924. Here an organization of the states on the Ohio River watershed was effected. Dr. J. E. Monger, Director of Health of Ohio, was elected chairman, and the writer served as secretary. The principle which has been enunciated with respect to industrial waste disposal matters in a recent report by Leitch of the United States Bureau of Mines, was here discussed. *"Good judgment should be used in not burdening industries within one state with large expenses for purification until adjoining states have established similar regulations. No real results can be accomplished until all affected are working in unison along the*

same lines and under similar regulations." Following this second national phenol conference, Sanitary Engineer Crohurst, of the United States Public Health Service, was detailed to make his accurate study of the extent of phenol waste pollution from a national standpoint, the cause, and the damage being done to public water supplies in the United States.

Fourth step

The scene next shifted to Pittsburgh, Pa., where on April 14, 1924, all the State Health Departments most interested, namely, Pennsylvania, Ohio, New York and West Virginia, met in conference with executives from all the by-product coke manufacturers from the several states to hear and discuss the report of United States Public Health Service and to formulate *joint similar policies* for coöperating states to carry out working with the industries. The position assumed by the leading steel and by-product coke companies of the country, and which was set forth by Mr. Elbert H. Gary of the United States Steel Corporation, was that the steel companies should coöperate with the State Health Departments even though large financial investments were necessary to collect and evaporate these objectionable phenol wastes by coke quenching. Phenol treatment plants to remove the phenol from the wastes were deemed necessary where the coke was produced for the domestic market and the coke not used in the steel industry itself.

The Interstate Stream Conservation Agreement of 1924

On November 17, 1924, three State Health Departments, Pennsylvania, Ohio and West Virginia, acting through their respective Health Commissioners, entered into and signed an agreement to inaugurate and carry out joint s milar policies with respect to phenol waste disposal. Under this agreement substantially complete elimination of discharge of phenol wastes into streams on the Ohio River watershed of these three states was called for. The aim of the agreement was to correct and prevent undue pollution of the interstate streams so that these streams might be maintained as suitable sources of public water supplies.

PROGRESS IN PHENOL WASTES ELIMINATION

On February 18, 1926, the states in conference at Pittsburgh took stock on progress made, at which time the State of Kentucky was

added to the group and became a signatory to the agreement. The progress since 1924 was found to be substantially as follows:

Pennsylvania: Of the six plants in Pennsylvania, four were disposing of phenol wastes satisfactorily by closed systems or lagoons, one plant had been dismantled and one was still discharging wastes to the Ohio River.

Ohio: Of the seven plants in Ohio, all had agreed to handle wastes satisfactorily and were in process of constructing the systems. Three companies were handling wastes so as to prevent discharge. Two new plants were planned and had agreed to use the closed system, putting no wastes into the rivers, in accordance with the new policy and agreement.

West Virginia: Of the six plants in West Virginia changes were in process at two plants to keep wastes out of stream. Two new plants were being built to conform with the new policy of handling phenol wastes. Two plants were still discharging phenol to the streams.

THE FINAL CHECK ON PHENOL WASTES ELIMINATION BY STATE ENGINEERS

On April 1, 1927, a survey by sanitary engineers of the respective states indicated that the single remaining Pennsylvania plant had agreed to proceed with a phenol wastes treatment works upon recommendations from the Sanitary Water Board of Pennsylvania. Ohio reported that phenol had been practically 100 per cent eliminated from the rivers. However, in one case, the treatment adopted was not satisfactory and a new, more efficient process would be installed. West Virginia reported that, of the plants formerly discharging into the Ohio and Monongahela Rivers, two were using coke quenching processes and the other had completed a phenol wastes treatment plant. Compliance with new policy was complete in West Virginia, except for one plant which promised to proceed as soon as the most practical treatment method could be determined upon. Of the 21 phenol wastes plants which were on the watershed, only one remained not complying with the recommendations of the Interstate Stream Conversation Agreement of November, 1924. It appears that coöperation between states to carry out one definite policy has been remarkably effective in reducing phenol pollution of the Ohio River watershed.

THE BIRTH OF A NEW ERA—COÖPERATION BETWEEN STATES AND INDUSTRY

Success in eliminating the objectionable phenols has lead to the formation of plans by nine states on Ohio River watershed to in-

augurate and practice similar policies with respect to other stream pollution matters. The original group of three State Health Departments is now enlarged to nine State Health Departments. These states, Pennsylvania, Ohio, West Virginia, Kentucky, New York, Maryland, Indiana, Illinois and Tennessee all are included in the Ohio River basin. In conference at Pittsburgh, September 27, 1926, all became signatories to the Interstate Stream Conservation Agreement. During the meeting the State Health Commissioners created a board of engineers of the signatory State Health Departments who should report to the Health Commissioners ways and means to make the agreement effective. Mr. W. L. Stevenson, Chief Engineer, Pennsylvania State Health Department, was named chairman and Mr. F. H. Waring, Chief Engineer, Ohio Department of Health, secretary. The group of the chief sanitary engineers of 9 states on the Ohio River watershed, where 15 millions of people live, met for the first time on April 29, 1927, in Columbus, Ohio, and organized as the "Board of Public Health Engineers, Ohio River Basin."

The recent progress achieved in eliminating objectionable phenol wastes by coöperation of states with industry has been so marked that the cry for "federal control of stream pollution" is becoming less insistent. Among the recommendations in the recent report of the Secretary of War dated June 4, 1926, and included as Document 417, 69th Congress, First Session, House of Representatives, is found the following:

> Because of the activity and steady progress of the states, manufacturers and industries in improving conditions, no federal legislation is recommended at this time so far as the effect of pollution on fisheries is concerned.

Dr. W. H. Frost of the United States Public Health Service, whose extensive stream pollution studies of the Ohio River over a period of years have recently been published, has stated that this concerted effort of states coöperating with industry on a common policy relating to the treatment of objectionable industrial wastes, gives infinitely more promise of success than the enactment of federal laws to regulate the pollution of interstate streams.

The Board of Public Health Engineers, Ohio River Basin, the new infant which was born as a result of the pains and efforts to conquer phenol pollution on the Ohio River, is headed by two sanitary engineers who are now engaged in the application of coöperative methods on industrial wastes disposal between State and Industry.

Mr. W. L. Stevenson, chairman, is chief engineer of Pennsylvania State Department of Health and the Secretary of the Sanitary Water Board of Pennsylvania. In that capacity he is constantly meeting with and inaugurating coöperative policies with different industrial groups to work out the most practical methods of wastes disposal. Full scale experimental work on disposal of tannery wastes now being carried on by the Sanitary Water Board indicates that Pennsylvania is actively coöperating with her industries.

Mr. F. H. Waring, secretary, is chief engineer for Ohio State Health Department, which department has during 1926 been carrying on the group system of dealing with industrial companies which have troublesome waste products to handle. The canning group in Ohio have already made substantial progress in arriving at a standard for treatment acceptable to the state. The acid iron group, the milk and milk products and pulp and paper mill wastes group have also indicated their willingness to coöperate with the State Health Departments.

The Board of Public Health Engineers, Ohio River Basin, at the conclusion of their meeting in Columbus on April 29, 1927, drew up a report for the consideration of the 9 State Health Commissioners signatory to the Ohio River Interstate Stream Conservation Agreement, suggesting definite policies which the Board felt would entirely clean up the little ends of the phenol pollution and expand the coöperative method and relationship between state and industry on industrial wastes disposal, to the end that the Ohio River and its tributaries may be conserved for future generations in condition fit for use as a source of public water supplies.

DISCUSSION

NORMAN F. PRINCE:[3] Early this spring, 1927, the Company that I represent received a complaint regarding the discharge, into the Genesee River, of the effluents from the gas manufacturing processes.

These effluents were analyzed and the results proved very interesting. By far the worst offender was the effluent known as "ammonia still waste."

The volume of this waste per day is 19,550 gallons and the phenol and phenolic bodies contained therein is 349.3 pounds, all calculated as C_6H_5OH.

[3] Chemist and Engineer, Rochester Gas and Electric Corporation, Rochester, N. Y.

The total amount of phenol as C_6H_5OH discharged from the plant in all effluents is 398.38 pounds per day.

When this complaint was received we immediately started to work with the object of introducing our effluents, especially those containing phenol or phenolic bodies, into the municipal sewerage system rather than to continue discharging them into the Genesee River as we had done for so many years. This was at the suggestion of Mr. Devendorf, Division of Sanitation, New York State Department of Health.

As this work progressed we were gratified to learn that the introduction of phenolic bearing wastes into raw sewage in no way interfered with the bacterial growth in the sewage.

This work is comparatively recent so it is not complete as yet.

The distance from our plant to the main sewage disposal plant is about $5\frac{1}{2}$ miles. I cannot give you the size of the sewers, but we have a two to three hour contact from our plant to the main disposal plant.

We believe that this contact between phenol bearing liquors and sewage is advantageous in that the organic matter present has an opportunity to act upon the wastes.

Our work up to this time has been carried out on "Raw Sewage" as it enters the plant. We are now going ahead and introducing ammonia still waste directly into an Imhoff tank having a capacity of 500,000 gallons sewage per day. Into this tank we are introducing 500 gallons of ammonia still waste, which you will remember I classified as the worst offender. This will give a comparative condition of 1 gallon of still waste to 1000 gallons raw sewage, which ratio exists in the larger plant, i.e., 20 million gallons sewage to 20,000 gallons of still waste. 20,000 gallons per day is our maximum figure and 20 million gallons per day is the sewage plant minimum.

As this study is coöperative in every detail the results will undoubtedly be published and, if as we hope, there is a real value in it, it will be available at that time.

There are no special features that I want to bring out at this time, except that in considering some of these wastes it must be borne in mind that in addition to phenols they also contain sulphides and cyanogen compounds.

I do not believe this organization is "tied in" in any way with the American Gas Association. I have only been a member about four months myself, but I believe that the problem of disposal of gas

plant effluents is too big for any single municipality or privately owned corporation to take up and push through. The problem is too large. I think that it is important to all of you.

I am speaking now from the standpoint of a gas manufacturing company which manufactures coke as a neccessary side line. We have to manufacture coke to make coal gas and the fraction of a cent per thousand which is added to our cost eventually hits your pocket as a consumer of gas. We have to get the money from some place.

The Public Service Commission usually takes good care of us, and in considering any methods of disposal of waste I believe the close coöperation of all of the major organizations of the country should be sought and the economic features and adaptability of any process should be worked out thoroughly and sanely.

The process of quenching coke with phenol bearing wastes is in my opinion one of the most objectionable things that could be inflicted on any community because we simply delay the time of getting them into the water supply.

The temperature of incandescent coke is very high and when quenched with these wastes they are simply scattered over the immediate and sometimes distant neighborhoods if the winds are right. These phenolic bodies also return with soil drainage.

They finally get into the river or lakes anyway.

Our plant is located in the heart of a city. Twenty or thirty years ago we were out of the city. The place was known as "Smoky Hollow," but now all around us are plants and less than half a mile away are homes. We are just so situated that if we become a nuisance from one cause or another we have simply got to take care of that nuisance and not run away from it.

I believe that this organization, through coöperation, can do a great deal toward solving this problem which is a nuisance. We admit we are a nuisance, but we have heretofore had no other place to put our wastes.

I know that the American gas industry as a whole considers the proposition of phenol bearing wastes as one of great importance. There is not a plant of any size in this country that is not being more or less worried by that very thing, not harassed, but worried and they are worrying because they know it is objectionable.

Chairman Howard: I should like to ask Mr. Prince, what led to the research work in Rochester?

Mr. Prince:[3] We have not altered the condition as yet. There is still research going on. The complaint was very good naturedly brought to us and we, just as good naturedly, took it up and went to work on it. I am not prepared to tell you all about the work because we want to clean up our own back yard first. I really think if we can get our own part of it cleaned up that the other manufacturers will follow suit.

Wellington Donaldson:[4] I can add very little to this discussion. The problems with which I am familiar are ones which have been brought out. The method of control has been condemned very severely it seems to me. I have seen coke-quenching methods used a good deal in western Pennsylvania, and so far as the stream is concerned I should say they are moderately successful as compared with the old conditions.

James M. Caird:[5] I wish to publicly express my appreciation of the coöperation which we have had from the Rochester Gas & Electric Company, and also the city of Rochester in affording facilities by which these phenol waste studies and their disposal are being investigated.

The history of the case is that the Rochester and Lake Ontario Water Company have from time to time received serious complaints regarding the flavor of the water. It would be impossible to state just what those flavors are. Everybody who takes a drink has a different definition of it.

The study reverts a good deal to wind directions. The Genesee River extends quite a distance into Lake Ontario. The intake of the Rochester Lake Ontario Water Company is about 4500 feet out into the lake and about a mile and a quarter to the west of the Genesee River where it is discharged into the lake. When we get an east wind we get a flavor, and when the wind shifts again we get a back lash. We have been trying various methods to overcome some of these flavors. I think up to a certain extent we have been fairly successful in that we have been using potassium permanganate, the quantity varying somewhat with the intensity of the flavors. Our chief engineer at the pumping station developed a very ingenious device for applying this potassium permanganate. When we have

[4] With Fuller and McClintock, Consulting Engineers, New York, N. Y.

[5] Chemist and Bacteriologist, Troy, N. Y.

these winds and our troubles are coming back to us we immediately try to get into action and head them off. We apply the potassium permanganate to the water before it goes to the coagulation basin, and to a certain extent we have been able to eliminate some of these troubles, but we have not taken all of the flavor out. With a fine taste you can sometimes get a little flavor. The public has not been as critical lately as they have been in the past and the work that is being done by the Rochester Company together with the city I believe will bear fruit.

C. R. Cox:[6] The Hudson Valley Coke and Products Corporation operates a large by-product coke plant at Troy, N. Y., about 6 miles above the Hudson River intake of the water supply system owned by the Rensselaer Water Company. The State Department of Health, therefore, required that a phenol recovery plant be installed at the coke works before the manufacture of coke was started, as this corporation did not wish to quench their coke by the "closed system," thereby evaporating the phenol. The phenol recovery plant installed as a result of this requirement has been described in chemical literature, but not in any of the waterworks journals. It may be of interest, therefore, to give a brief description of this phenol recovery plant.

Ammonia liquors containing the phenol from the primary gas scrubbers of the coke plant are passed through benzol scrubbers where phenol is absorbed by the benzol. The benzol is then pumped through caustic soda scrubbers where the phenol reacts with the caustic soda to form sodium phenolate. The sodium phenolate is then treated with sulfuric acid to liberate the phenols, sodium sulfate being also formed by the reaction. The dephenolated benzol is used over again in the scrubbers and thus the process is continuous.

Rather poor efficiencies were secured at first, due to the fact that the caustic soda reacted with the carbon dioxide also removed with the phenols so that sodium carbonate was formed. A water scrubber was inserted, therefore, at a later date between the benzol scrubbers and the caustic soda scrubbers, so the caustic soda solution could be used for much longer periods. The actual efficiencies in the removal of phenols have varied from 70 to 98 per cent, frequently averaging 90 to 95 per cent for several weeks. These efficiencies are not altogether satisfactory, because, with an assumed efficiency of 85 per cent, about

[6] Division of Sanitation, State Department of Health, Albany, N. Y.

30 pounds of phenol are discharged into the Hudson River per day. These phenols do not mix thoroughly with the river flow but pass down the river toward the water supply intake and thus have led to difficulties at intervals.

The Rensselaer water filtration plant consists of typical mechanical filters where double chlorination is practiced, due to the heavy pollution of the Hudson River. The dose of chlorine added is very heavy, especially during the winter months when the river is covered with ice and the stream flow is at a minimum. Difficulties due to chlorophenol tastes have been met with, therefore, at times since the coke plant has been in operation. These difficulties could be traced to the inefficiency of the phenol recovery plant at first, but at other times it was difficult to explain the prevalence of chlorophenol tastes in the chlorinated river water. As the filtration plant is operated only at night, the State Department of Health suggested that the coke plant discharge the wastes containing residual phenols into the river between 6 a.m. and 12 noon. This precaution has been quite successful, although it would be very advisable for the phenol recovery to be made more efficient. The Hudson Valley Coke and Products Corporation, therefore, is investigating the problem.

Since the above discussion was held, it has been ascertained as a result of these studies that the relatively poor efficiencies of the existing plant have been due to the fact that emulsions are formed in the benzol scrubber which prevent the efficient absorption of the phenols. The designer of the phenol recovery plant has developed a modified design wherein the benzol has been replaced as an absorbing medium by tar oils made by the fractional distillation of coke plant tars. The preliminary work seems to indicate that this modified plant will produce much higher efficiencies of phenol recovery than the older plant.

Chairman Howard: Mr. Cox, where is that described?

Mr. Cox:[3] The phenol recovery plant mentioned above is described in the March, 1926, issue of *Industrial and Engineering Chemistry*. The improved plant is described in the September, 1927, number of the same journal.

PROGRESS IN CONTROL OF OIL POLLUTION[1]

By Almon L. Fales[2]

The Committee on Industrial Wastes in Relation to Water Supply, of which the writer is Chairman, has made four progress reports which have been published in the Journal, one each year for the last four years. It was decided by the Council on Standardization that instead of presenting another progress report this year, the time be devoted to individual papers of interest within the field covered by this Committee. The writer was requested to present a paper on progress in control of oil pollution.

OIL POLLUTION IN RELATION TO WATER SUPPLY

The first progress report of the Committee on Industrial Wastes in Relation to Water Supply (1) cited a considerable number of water supplies that had been injuriously affected by discharges from oil wells and oil refineries.

Pollution from oil wells. The trouble from oil wells is due to the discharge of oil and salt water. The crude oil may be separated from the water by a suitable skimming tank used in connection with the purification plant. If allowed to escape into a water supply, the oil imparts to the water a disagreeable taste and odor and interferes with coagulation, filtration and chlorination processes, increasing water purification expense. The salt water increases the hardness of the water supply and gives the water a brackish taste. Water supplies have been ruined in this way. It is impracticable to remedy the trouble by treatment of the water. When the pollution reaches the limit of tolerance, it is necessary to secure a new water supply.

F. M. Veatch, Consulting Engineer of Kansas City, has informed the writer that considerable progress has been made in Kansas in the care of salt water from drilling operations. In one of the Kansas fields, it has been found practicable to pump the salt water back into the water sand through the annular space between the strings

[1] Presented before the Water Purification Division, Chicago Convention, June 10, 1927.

[2] Of Metcalf & Eddy, Engineers, Statler Building, Boston, Mass.

of casing. There does not appear to be any practical scheme of caring for salt water from isolated wells, except the customary salt water ponds which are, at best, a makeshift arrangement. It is reported that a company in Oklahoma is contemplating the evaporation of the salt water from oil wells for the production of sodium chloride and calcium chloride on a commercial basis.

The legislature of Kansas recently passed an Act authorizing the State Board of Health to prevent stream pollution detrimental to the aquatic life of the State. Ernest Boyce, Engineer of the Kansas State Board of Health, points out that this Act gives the Board of Health authority with regard to salt water pollution, including the carrying on of investigational work, because such pollution may easily be detrimental to aquatic life. He states that the Attorney General is now planning a conference of representative oil producers and geologists to discuss ways and means whereby oil may be obtained from the ground without the volume of salt water that is being pumped at the present time.

Pollution from oil refineries. In the case of oil refineries, the principal effect on water supplies has been due to the wash water from the agitators in which the crude gasoline and kerosene are purified. These wastes contain taste and odor-producing substances and interfere with purification processes. Aeration in addition to coagulation and filtration has proven very beneficial, but is not a complete remedy if the extent of pollution is too great. In such cases, more complete removal of the taste-producing substances at the source is essential.

F. M. Veatch states that the most practicable method thus far devised for controlling pollution of water supplies by refinery wastes is ponding of the wastes and discharge only at high river stages. Ernest Boyce, Engineer of the Kansas State Board of Health, has furnished the following information in regard to the method of handling the wastes from the refinery of the Standard Oil Company of Kansas at its Neodesha plant:

> The company has provided large impounding reservoirs which will hold 90 days' flow of wastes from the refinery, and in this manner protects the water supplies of Independence, Coffeyville and Cherryvale. These reservoirs cover about 15 acres and are about 12 feet deep. A daily record is made of the operation of these reservoirs, which is filed monthly with this department. Liaison is maintained between the refinery and the Water Superintendent at Independence, the agreement being that no refinery waste will be discharged without the consent of the Water Superintendent, which is not given unless he is convinced that the river is at a stage which will permit sufficient dilution to avoid complaint from taste.

SOURCES OF OIL POLLUTION

There are various causes of oil pollution of waters, practically all of which are potential sources of injury to water supplies. The United States Bureau of Mines after extensive field investigations of coast waters reported the following sources of oil pollution (2):

Oil-burning and oil cargo vessels
Ship repair yards
Oil terminals and refineries
Oil fields
Gas plants
Other industrial plants
Sewers

Oil-burning and oil cargo vessels. It was concluded that a very large proportion of the oil pollution was due to oil-burning and oil cargo vessels resulting from the pumping out of oil-contaminated ballast water and bilge water, cleaning and flushing operations including sludge from oil storage tanks or compartments, and accidents including stranding, collision and sinking. Ballast water was considered the principal source. Even when the oil is discharged long distances outside the 3-mile limit, it may be carried into territorial waters by winds, tides and currents. Oil-burning vessels which now comprise half of the total power shipping carry such enormous quantities of oil, either as fuel or as cargo, that even though the losses are only a small fraction of the total quantity carried, they are of considerable importance from the standpoint of oil pollution.

Ship repair yards. In the case of ship repair yards, more or less waste oil gets into adjacent waters at times, even where efforts are made to prevent it. If the bottom plates are to be removed or if the damage has been so great as to prevent the cleaning of the oil tanks before the vessel is raised on the dry-dock, large quantities of oil wastes escape into the water. Because of the lack of adequate means for preventing the escape of oil or of recovering it from the water, this was considered one of the important sources of pollution of waters.

Refineries and oil terminals. Oil pollution from refineries may be caused by leakage from stills, pipe lines, filling-racks, draining of tanks and spills in the yards. Most of the large refineries were found to have complete drainage systems and efficient separators for recovering the oil, although some of these separators were inefficiently operated. Other refineries, particularly some of the smaller ones, were not ade-

quately equipped for recovering the lost oil and constituted a continuous source of pollution which was especially bad during heavy rains when oil spilled in the yard was washed into nearby streams.

Some oil is lost in unloading and loading operations at the docks in spite of precautions and, in the absence of adequate floating booms and suitable skimming facilities, may result in considerable pollution. This statement applies also to oil-terminals and oil-distributing stations which handle very large quantities of oil.

It was concluded that, under the existing conditions, oil refineries and oil-terminals constituted one of the important sources of oil pollution on the Atlantic and Gulf coasts.

Oil fields. Pollution of water supplies by oil field operations has already been referred to. Investigations by the Bureau of Mines led to the conclusion that oil fields are of minor importance as a general source of oil pollution.

Gas plants. In the manufacture of carburetted water gas, considerable quantities of tar or heavy oil are formed and pass away as water mixtures. In spite of the fact that the majority of plants visited were making an effort to remove the tar by means of a series of gravity type separators, it was concluded that, under existing conditions, gas works constitute an important source of oil pollution, although such pollution is usually local in its effects.

Other industrial plants. Power houses and industrial plants in general using oil as fuel may become sources of oil pollution due to improper handling and storage of the oil. Railroad yards and round houses where the railroads use oil for fuel may be sources of serious oil pollution. Such plants are a minor source of general oil pollution and by the use of available methods and devices, this source can be practically eliminated.

Sewers. Although the discharge from sewers was not a major source of oil pollution, serious trouble from this source has been experienced at times in some localities. Unless some consistent policy is maintained for handling waste oil from private and public garages and industrial plants connected with sewers, this may become an important source of oil pollution.

EFFECTS OF OIL POLLUTION

Aside from its effect on water supplies previously referred to, oil pollution of waters has a number of deleterious effects, including the following, which are discussed in the report of the Interdepartmental Committee on Oil Pollution (2, Appendix 3, pp. 25, 50–59):

Damage to bathing beaches and shore property
Destruction of aquatic life
Increasing fire hazard to shore structures and floating craft
Injurious effects on public health

Bathing beaches and shore property. The presence of oil on beaches and other shore waters used for recreational purposes renders them unattractive and unfit for bathing. The oil is not only objectionable on the body and difficult to remove therefrom, but is injurious to bathing suits and if carried into houses, damages floors, floor coverings and clothing. It also causes fouling of pleasure craft.

Oil pollution at seaside resorts naturally tends to depreciate the value of the property. Much information in regard to oil pollution at bathing beaches in 1921–1922 is given in a report by F. W. Lane, Petroleum Chemist of the United States Bureau of Mines, A. D. Bauer, Associate Petroleum Chemist of the Bureau of Mines, H. F. Fisher, Mechanical Engineer representing the American Petroleum Institute and P. N. Harding, Mechanical Engineer representing the American Steamship Owners Association (3). It was concluded that some action is necessary to ensure the maintenance of beaches in satisfactory condition for use.

Aquatic life. Fish may be trapped in bodies of water covered with oil and eventually suffocated, but the chief trouble in the fishing industry is the injurious effects of the oil on spawning grounds and on the minute plant and animal food supply in the water, which cause the fish to migrate.

Shellfish in the larval stage, swimming about just beneath the surface of the water, are destroyed by the presence of an oil film. Oil slime on the bottom undoubtedly has an injurious effect on the setting of the oysters. Experiments indicated that oil pollution unless very severe will not kill adult shellfish, but will render them unfit for food.

Danger to Fisheries from Oil and Tar Pollution of Waters is the subject of a report by J. S. Gutsell, Scientific Assistant of the United States Bureau of Fisheries (4).

Water-fowl coming in contact with heavy oil and tarry substances get their feathers matted together, disabling them and causing them to perish from hunger and exposure. This condition has caused extensive destruction of aquatic bird life.

Fire hazard. Oil pollution increases the fire hazard to shore structures and floating craft. When crude oil is freshly spilled in water,

there is danger of direct ignition due to the presence of readily volatile substances, such as gasoline and kerosene, but the fire hazard from oil pollution is due very largely to the danger of propagating fires started from other sources.

The control of oil pollution in Massachusetts waters is vested in the Department of Public Safety and Regulations have been prescribed by the Fire Marshal. These Regulations refer to the discharge of "crude petroleum or its products or any other inflammable oil, or any bilge water. . . . ." According to information received from Mr. Evans, who has direct charge of oil pollution control, cases have recently been brought against two oil refining companies for violation of the law. In one case, the company was found guilty, but has appealed. In the other case, the company was found not guilty, because it was proven that the oil complained of was not "crude petroleum" and was not "inflammable."

Public health. Oil pollution is detrimental to public health principally because it discourages healthful water and shore recreation. The Effect of Oil Pollution of Coast and Other Waters on the Public Health is the subject of a report prepared by F. W. Lane and A. D. Bauer of the United States Bureau of Mines, H. F. Fisher representing the American Petroleum Institute and P. N. Harding representing the American Steamship Owners Association (5).

MEANS OF PREVENTION OF OIL POLLUTION

Investigations by United States Bureau of Standards. The character of oil-water mixtures and devices for removing the oil were investigated by the Bureau of Standards (2, Appendix 5, pp. 76–84). Among the conclusions were the following:

> From 95 to 99 per cent of the fuel oil in such (ballast water) mixtures may be termed floating oil, i.e., it will normally rise to the surface of a free water mixture within 60 to 120 seconds.
>
> From 1 to 5 per cent of the fuel oil in such mixtures may be termed suspended oil, i.e., it may require from 2 to 4 hours settling before it clears the free water.
>
> A small fraction of 1 per cent of the fuel oil in such mixtures may be termed emulsified oil, i.e., it may require several days or weeks' settling before it clears the free water.
>
> No great difficulties are usually encountered in the removal of floating oil from ballast water mixtures by comparatively simple gravity separators.
>
> No gravity separator of a size suitable for use on shipboard can be expected to remove suspended or emulsified oil.

The recommendations were as follows:

1. That gravity-type separators be recognized as suitable for the separation of oil from ballast water on shipboard in non-territorial waters.

2. That separators which, during thorough test at sea under average operating conditions, can show an effluent averaging not more than 0.01 of 1 per cent oil, be approved for such use provided they are equipped with either (*a*) satisfactory automatic control; or (*b*) manual control whereby the operator may determine the character of influent and effluents constantly, and control the rate of flow through the separator instantly without leaving his station.

Investigations of Bureau of Mines. The Bureau of Mines in cooperation with the American Petroleum Institute and the American Steamship Owners Association has made an investigation of available methods and devices for handling oil-contaminated water and has recently issued a publication on the subject (6).

The methods considered include those designed to dispose of oil-contaminated water and other oil wastes by the use of facilities provided on land or in port and those designed for use on ships. With respect to the former, the following statement is made:

Of the three methods for disposing of oil wastes from ships by means of facilities provided in port, petroleum harbors seem impractical because of delays to shipping and the consequent decrease in earnings, and bilge-water pumping stations seem impractical in large ports because of the enormous cost of installation. The use of collecting barges appears to be the only feasible and practical method for all ports.

The barge method was carefully studied as applied to the port of New York and it was estimated that the initial investment required to take care of all the oil-contaminated water that would have to be handled in the harbor would be approximately $900,000 and that the net annual expense would be about $255,000, corresponding to a total cost of about $70 per vessel per call.

With respect to the methods for use on the ships, it is stated that "gravity" separating devices appear to be the most promising. Descriptions and illustrations of different types are given. It is believed that bilge water being correspondingly small in volume can be treated by means of a small pump and flexible hose suction discharging into a separating tank from which the oil is skimmed at intervals and returned to the fuel storage tank and the water drained back into the bilge.

So far as oil-burning ships are concerned, it is believed that the most satisfactory ultimate solution will involve the use of a separat-

ing device on each individual ship and facilities in harbors for collection and proper disposal of heavy sludge and other oily wastes that the separator will not handle. If a completely successful device for separating oil from ballast water on general cargo vessels cannot be readily developed and applied, one that would satisfactorily reduce the bulk of the oil-water mixture to a large extent would greatly facilitate subsequent collection by barges which will presumably be required in any case to dispose properly of tank sludge and other oily refuse.

Methods and devices for separating oil from wastes discharged by ship-yards, oil refineries and gas plants were considered and the following conclusion was reached (6, p. 66):

> It is believed that the apparatus now available for handling oil-water wastes from land plants are adequate, when properly installed and used, largely to eliminate oil pollution from such establishments—with the possible exception of ship-repair yards, where the normal conditions of operation are such that the control and proper disposal of oil refuse and oil wastes are very difficult. Ship-repair yards will require the further development of means for coping effectively with this situation.

Control of oil pollution in Rhode Island. Even though adequate means be provided for preventing oil pollution, proper operation and inspection are necessary to secure satisfactory results. An excellent example of the control of oil pollution is furnished by the State of Rhode Island (7). Through adequate laws, strict rules and regulations and coöperation with parties causing pollution, serious oil pollution conditions were brought under control.

In the great majority of cases, spills on shore at the oil companies in Rhode Island are now prevented from reaching the public waters by dikes, lead-back drains and similar protective measures.

Under the legislation established by the Board of Purification of Waters, pumping out bilge water or water ballast from oil tankers is absolutely prohibited in Rhode Island waters. It is now the custom for all oil tankers while loading or unloading to display a red flag by day or a red lantern by night as a caution signal to passing shipping. All steamship companies operating in Rhode Island waters have been officially requested by the Board to instruct their Captains to proceed at slow speed while passing oil tankers displaying this signal.

On the unloading dock, all the oil companies have now installed a tight section with a raised edge or rail 6 inches or more in height to catch any oil which may be spilled at the point where the unloading

hose comes over the side of the vessel and connects with the shore pipes lines. The oil companies have also installed a drip pan or sand box to catch the oil which runs out when the hose is disconnected.

All waste waters from oil distillation and refining plants must be passed through properly designed separators. In some separators, the final effluent is passed through some form of filter to remove semi-emulsified oil which will not separate by gravity. Sand has been used, but coke or fine cinders is better. Mr. Gage considers an excelsior mat most advantageous because this can readily be removed and burned.

To reduce the fire hazard, storage tanks are usually located in a pit or surrounded by an embankment or wall to retain the oil in case of an accident or collapse of the tank. This provision also serves as a safeguard against oil pollution. Pipe lines running along the docks or on the water fronts are usually carried in a box filled with sand or sawdust or in a cement-lined conduit draining to a pit or slop tank where any oil leakage may be collected and recovered.

The car-loading yards require considerable supervision to prevent oil spills. The Board insists that all direct drainage connections from car-loading yards into the harbor be removed or effectually sealed. Most of the oil companies now keep the surface of the ground in the loading yard well sanded to absorb minor drips and spills. The oil-soaked sand is scraped off and carted away. Instead of being discharged between the tracks or run into the harbor, the oil sludge and drainage from the tank cars are now discharged into cans or into suitable slop tanks placed beneath the tracks.

Education is considered one of the most important factors in preventing oil pollution.

In a recent letter, the Clerk of the Board of Purification of Waters states as follows:

> We believe that the constant inspection and supervision carried on through agents of the Board is indispensable to keep up the regular and careful use of preventative measures. We believe that emphasis must be continued upon the adoption of safety measures by plants using fuel oil. Escape of such oil is rarely expected yet an accidental discharge will usually readily find its way into the public waters through the drainage system unless some preventative measure has been adopted in anticipation. The Board of Purification of Waters is continuing its survey of such plants and making from time to time suggestions for installation of methods to prevent accidental discharges of oil escaping into the public waters. It is planned shortly to prepare a circular for distribution among manufacturers generally in Rhode Island, calling

attention to methods which have been suggested and adopted at other plants to prevent accidental escape of oil.

CONFERENCES AND LEGISLATION ON OIL POLLUTION

The War Department has jurisdiction over stream pollution from the point of view of navigation, under the River and Harbor Act approved March 3, 1899, and other acts amendatory or supplemental thereto, but no specific mention is made of pollution by oil or oil wastes, which had not become an important question when the legislation was enacted.

Provision for Control of Pollution in New York Harbor. In addition to the River and Harbor Act of 1899 is the Act of June 29, 1888, amended by the Act of August 18, 1894, for the prevention of pollution in New York Harbor. This Act deals with pollution not only by the waste matters referred to in the general act of 1899, but also with respect to oil and oil wastes. Under this Act the supervision of New York Harbor is placed in the hands of the Supervisor of the Port of New York and a naval officer is detailed for this particular work, and the expenses of supervision are covered by special Congressional appropriations.

Joint Resolution of Congress for International Conference on Oil Pollution. Several bills relating to oil pollution were introduced in Congress in the fall of 1921 and referred to the Committee on Rivers and Harbors which held hearings (8) at which representatives of a number of civic associations, Federal and state departments and other interested parties testified. It was brought out that the problem could not be completely solved without international agreement. The outcome was a Joint Resolution of Congress, approved July 1, 1922 (9) requesting the President to call a conference of maritime nations, with a view to the adoption of effective means for the prevention of pollution of navigable waters by oil-burning and oil-carrying steamers, by the dumping into such waters of oil waste, fuel oil, oil sludge, oil slop, tar residue and water ballast.

This resolution was referred by the President to the Secretary of State and an interdepartmental committee was formed consisting of representatives of the following departments:

State Department
Treasury Department
War Department
Navy Department

Interior Department
Department of Agriculture
Department of Commerce
Shipping Board.

These departments undertook investigations of different phases of the oil pollution problem, including extent of pollution, causes, effects and remedies. The report of the Interdepartmental Committee will be referred to later.

Atlantic City Conference on Oil Pollution. A conference on oil pollution called by the League of Atlantic Seaboard Municipalities was held at Atlantic City August 10 and 11, 1922. This conference was attended by about 75 delegates including Federal, state and municipal officials, representatives of civic associations and others. Much information was presented in regard to the extent of oil pollution, its causes, effects and the possible remedies. Resolutions were passed, endorsing certain bills before Congress. The Conference resolved itself into a permanent organization under the name of the National Coast Anti-Pollution League, and David M. Neuberger, Esq., was elected President.

National Coast Anti-Pollution League. A second meeting of the National Coast Anti-Pollution League was held at Atlantic City, New Jersey, October 1, 2 and 3, 1923, with an attendance of about 135, including Federal, state and municipal officials, representatives of chambers of commerce, oil companies, steamship companies and oyster growers, and others (10). Round table meetings of different groups were held in addition to the general sessions. Resolutions were adopted favoring certain Federal legislation and recommending state legislation including the formation of state sanitary and economic water boards, to have control of water resources.

Oil Pollution Act of 1924. Several bills relating to oil pollution were introduced in Congress in 1923. A hearing on three of these was held before a subcommittee of the Committee on Commerce of the United States Senate (11), at which oral statements were made by a considerable number of interested parties and many written communications received. Most of the pollution bills were referred to the Committee on Rivers and Harbors, which held extensive hearings (12). The outcome was the so-called oil pollution act of 1924, which became law on June 7, 1924 (13).

This Act provides that, except in certain cases of accident or emergency or as permitted by regulations which the Secretary of War is

authorized to prescribe, it shall be unlawful to discharge oil into or upon the coastal navigable waters of the United States from any oil-burning or oil-transporting vessel.

The penalty for violation of the Act is a fine not exceeding $2500 nor less than $500 or by imprisonment not exceeding one year nor less than 30 days, or by both such fine and imprisonment, for each offense. Clearance of such vessels from a port of the United States may be withheld until the penalty is paid, and said penalty shall constitute a lien on the vessel. Provision is also made for revoking the license of the officer of the vessel.

For the administration of the Act the Secretary of War is authorized to make use of the organization, equipment and agencies employed in the improvement of rivers and harbors and the officers and agents in charge of such improvements and the assistant engineers and inspectors employed by them; and the officers of the Customs and Coast Guard Service are charged with the arrest of violators of the provisions of the Act.

Section 9 of the Act also authorized and directed the Secretary of War to make an investigation to determine what polluting substances are endangering or interfering with navigation or commerce upon navigable waters or the fisheries therein, and to report the results of his investigation to Congress within two years, together with such recommendations for remedial legislation as he deems advisable. For this investigation, the sum of $50,000 was authorized in addition to funds already appropriated for river and harbor examinations, surveys and contingencies, which may be drawn upon.

Report of War Department on Pollution Affecting Navigation or Commerce on Navigable Waters. The report of the investigation of pollution of navigable waters, made by the War Department in compliance with the Oil Pollution Act of 1924, was presented to Congress on June 4, 1926 (14).

In addition to domestic sewage the report lists the following industries as the sources of the more injurious polluting substances:

a. Oil
b. Coal mining washery wastes and acid mine drainage
c. Coal distillation
d. Metal trades—pickling, cleaning and plating wastes
e. Pulp and paper mills
f. Tanneries
g. Textile industries—washing, bleaching and dyeing wastes
h. Miscellaneous including distilleries, storage battery service stations, rubber reclaiming, canning factories, creameries and chemical plants

These sources of pollution are discussed and the effects on navigation or commerce and on fisheries are described. A table is given, showing the navigable waters affected by pollution, the principal sources of the pollution and the injurious effects. A summary of the findings is included, and the existing Federal laws relating to the pollution of navigable waters are summarized and data given with respect to state control of pollution. The report states that industries are coöperating with local authorities in a study of the problem and devising methods by which injurious substances in the wastes can be recovered or rendered less harmful before discharge into the waterways. It is stated that industries engaged in the production, storage and transportation of oil are installing more efficient recovery devices and are more zealous in their efforts to prevent the escape of oils into waters by accident or otherwise.

No Federal legislation is recommended at this time, with respect to pollution in general, nor in regard to acid mine drainage in particular. With respect to oil pollution it is recommended (14, p. 28):

> . . . . that the oil pollution act of 1924 be made applicable to the discharge of oil from any source, into or upon the coastal navigable waters of the United States, or into or upon any of the Great Lakes, their harbors and their connecting channels.

Present Status of Oil Pollution Legislation. The Oil Pollution Act of 1924 applies only to oil-burning and oil-carrying vessels. Several bills extending the Federal jurisdiction to land sources were introduced in the last Congress and referred to the Committee on Rivers and Harbors, but no action was taken on them. Presumably similar bills will be introduced in the next Congress and unless oil pollution from land sources is reduced to negligible amounts it is probable that further legislation will be enacted.

Report of Interdepartmental Committee on Oil Pollution of Navigable Waters. The Interdepartmental Committee formed as a result of the joint resolution of Congress calling for a conference of maritime nations on oil pollution, made its report to the Secretary of State on March 13, 1926 (2). This report deals with the following general subjects:

I. Authority and organization of the Committee
II. Description of the construction work and investigations made at its instance by departments and agencies of the Government
III. Description of steps taken by the United States, to deal with the problem

IV. State measures taken to deal with the problem in foreign countries
V. Summary: conclusions and recommendations.

The report also contains the following appendices:

1. Joint resolution of Congress, 1922
2. Oil pollution act of 1924
3. General report of the Bureau of Mines on pollution by oil, of the coast waters of the United States
4. Report of the Bureau of Mines, entitled "The Action of Sea Water on Fuel Oil"
5. Preliminary report of the Bureau of Standards, on the Character of Oil-Water Mixtures occurring on shipboard, and the investigation of devices designed for the removal of oil from such mixtures
6. Report of Bureau of Fisheries: Preliminary Investigation of the Effect of Oil Pollution on Marine Pelagic Eggs
7. Report of the United States Shipping Board
8. Report of the Department of State on the problem, and efforts to deal with it in foreign countries

It is not within the province of this paper adequately to abstract this report, but it is commended to all who are interested in the subject of oil pollution.

International Conference on Oil Pollution. After the Interdepartmental Committee had made its report, a conference of maritime nations was called, in accordance with the Joint Resolution of Congress, previously referred to. This conference was held at Washington June 8–16, 1926. In addition to the United States, delegates were present from the following 12 nations: Belgium, British Empire including Canada, Denmark, France, Germany, Italy, Japan, Netherlands, Norway, Portugal, Spain and Sweden.

Senator Frelinghuysen was elected Chairman. Committees were formed, to consider the following matters:

Facts and causes
Classification
Zones and enforcement
Admeasurement
Drafting
Technical

The minutes of the meetings have been published in English and in French in a United States Government document (15).

It was agreed that the report of the American Interdepartmental Committee formed, in the main, a sound basis for the work of the

Conference. The Conference reached an agreement on the following recommendations to the respective governments, for adoption by international agreement (15, pp. 438–442).

(1) That the Governments concerned provide for a system of prescribed areas in waters off their coasts beyond territorial limits (if necessary, after consultation with neighboring governments) within which vessels of the classes mentioned in recommendation No. 4 shall not discharge crude, fuel or diesel oil or mixtures having an oil content greater than that stated in recommendation No. 5.

(2) That along coasts bordering the open sea, such areas shall not extend more than 50 nautical miles from the coast, except, that if such extent is in particular instances found insufficient because of the peculiar configuration of the coast line or other special conditions, the Government affected may extend its area to a width of not exceeding 150 nautical miles, after consultation with neighboring governments, if necessary.

(3) That due notice of the establishment of any areas shall be given to the governments concerned in the form of marked charts or otherwise.

(4) That the regulations adopted with respect to prescribed areas shall be applicable to all seagoing vessels other than war vessels, carrying crude, fuel or diesel oil, in bulk as cargo or as fuel for boilers or engines, due consideration being given to the special necessities of small vessels. It is assumed that the naval authorities of each country will take the necessary measures to ensure that vessels classed as war vessels shall take every possible precaution to prevent oil pollution.

(5) That the discharge of oil or oily mixtures be prohibited within such areas if the oil content exceeds 0.05 of one per cent, that is, if it is sufficient to constitute a film on the surface of the sea visible to the naked eye in daylight in clear weather.

(6) That each government agrees to use all reasonable means to require its vessels to respect all such areas.

(7) That no penalty or disability of any kind whatever in the matter of tonnage measurement or payment of dues be incurred by any vessel by reason only of the fitting or any device or apparatus for separating oil from water.

(8) That dues based on tonnage shall not be charged in respect of any space rendered unavailable for cargo by the installation of any device or apparatus for separating oil from water.

(9) That the term "device or apparatus for separating oil from water" as used in recommendations Nos. 7 and 8 shall include any tank or tanks of reasonable size, used exclusively for receiving waste oil recovered from the device or apparatus, and also the piping and fittings necessary for its operation.

(10) That each government should carefully observe the operation and effect of the area system off its coasts, and exchange information thereon with the other interested governments, so that if, after reasonable experience, any government may consider that such areas do not sufficiently protect its coasts, or that pollution beyond such areas has become or threatens to become a menace, such government may be in position to raise with the other governments

the question whether the discharge beyond the limit of such areas of oil or oily mixtures constituting a nuisance should be prohibited.

(11) That a central agency be established as soon as practicable for receiving, coördinating, and circulating to the governments concerned information of interest relating to the system of areas, the establishment of which is suggested in the foregoing recommendations, the experience with that system and other data deemed advisable.

A Draft of Convention was adopted, for the consideration of the respective governments, to take effect as soon as the ratification of five of the governments represented at the Washington conference of June 1926, shall have been notified to the Government of the United States.

The writer has been in communication with the Secretary of State and has been advised that it is expected that this Government will shortly take steps to ascertain from the governments whose representatives attended the Preliminary Conference, their views with regard to the Draft of Convention, and upon receipt of these views it is hoped that steps may be taken looking to the adherence by the interested governments to an agreement substantially in the form of the Draft of Convention. Various shipping interests and other interested organizations in the United States and in Great Britain have agreed that the recommendations of the preliminary conference should be voluntarily put into operation.

PRESENT STATUS OF OIL POLLUTION

Information from Kenneth Allen, regarding Conditions in New York Harbor. In a recent letter Kenneth Allen, Sanitary Engineer of the City of New York, Board of Estimate and Apportionment, states that conditions in New York Harbor have continued to improve during the past two or three years. This he believes is due in part to the general publicity given the matter and the more general realization of the damage that was being done, and in part to increased vigilance by the Supervisor of Harbor.

There are occasional complaints at bathing beaches in the summer, but much fewer than formerly. The Harbor Supervisor, Capt. K. M. Bennett, U.S.N., stated that oil and gas companies, shipyards and those engaged in cleaning oil tanks or vessels are all more careful to prevent spills than they were. Nevertheless, there are still temporary conditions when much oil either as scum or more often sleek, is in evidence in the lower East River and Upper Bay, especially

along the Brooklyn shore and in the Kill von Kull. The small tributaries, Newtown Creek and Gowanus Canal in Brooklyn, are still liable to heavy oil pollution from industries along their shores.

Report of New York Joint Legislative Committee. The report of the Joint Legislative Committee in reference to the Pollution of Waters of the State of New York, dated February 28, 1927, states that in 1923 conditions at all the beaches near New York were very bad, but that a great improvement is noticeable at the present time, although much still remains to be done. The Committee makes the following recommendations:

1. Strict enforcement of the Oil Pollution Act and Harbor Rules and Regulations.
2. Policing the Harbor must be more thorough, which can only be brought about by the addition of more patrol boats properly manned and of a modern type.
3. The extension of the "Oil Pollution Act" and the entering by the United States into an international agreement with other maritime nations to prohibit the dumping of oil, oil laden bilge, garbage and refuse at sea within prescribed areas sufficiently removed from the coast to prevent such from reaching our beaches.

Information from President of National Anti-Pollution and Conservation League. David W. Neuberger, Esq., President of the National Anti-Pollution and Conservation League (formerly National Coast Anti-Pollution League), in a recent letter states that the League is still active in the matter of elimination of oil pollution of waters and at the present time is conducting a radio campaign against pollution, over WGL, New York City. His opinion is that pollution of the coastal waters has not and will not be eradicated without prohibition against land plants.

CONCLUSION

It is generally reported that oil pollution conditions have improved decidedly in recent years, due to the arousing of public opinion, agitation of the subject, legislation, coöperation, education and other causes, although conditions in many places are still far from satisfactory. The indications are, however, that the oil pollution problem is well on the way to solution.

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(3) United States Public Health Reports, vol. 39, no. 51, December 19, 1924, Reprint No. 980.

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(9) Public Resolution No. 65, 67th Congress.

(10) Transactions of the National Coast Anti-Pollution League, Second Annual Meeting, Atlantic City, New Jersey, October 1, 2 and 3, 1923.

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QUANTITATIVE STUDIES OF PHENOLS IN WATER SUPPLY[1]

By Wellington Donaldson[2] and R. W. Furman[3]

The Water Department of the City of Toledo had a comprehensive survey made of its water resources in 1925 and 1926 in order to define policies to be adopted in future extensions or developments of its public water supply. This survey reviewed not only the limitations of the present supply taken from the Maumee River at a point near the upper or southerly end of the city, but investigated as well the probable quality, quantity and cost of a supply to be developed from the upper river, and the probable quality and cost of a supply to be developed from an intake in Lake Erie. In connection with the studies of water quality an extensive sampling program was carried out, as follows:

a. Collection thrice weekly by motor boat or tug from the lower stretch of the Maumee River opposite and below the water works intake out as far as the harbor light, at the outer edge of Maumee Bay.

b. Collection thrice weekly by tug during the navigable season from Lake Erie 5 miles S.E. of the harbor entrance at suggested intake sites. During the winter, a few samples were collected off-shore through the ice at these points.

c. Collection from regular day steamers of a series of samples from Lake Erie from the mouth of the Detroit River to the entrance of Maumee Bay.

d. Collection weekly or oftener from the Maumee and Lake Erie Canal and the Maumee River above the Toledo intake at various points up to and including the Defiance intake, also the Auglaize and Tiffin Rivers near Defiance, the Blanchard and Ottawa Rivers near Kalida, Ohio.

e. Collection, occasionally, during the beet sugar season, from the Blanchard River at Ottawa, at the Putnam-Hancock counties line and at Findlay.

f. Collection at least twice of industrial wastes discharging into the lower Maumee, Ten-Mile, Otter and Duck Creeks.

The special samples, some 3600 in number, covering a period from September 3, 1926, to June 21, 1927, were handled in the Toledo

[1] Presented before the Water Purification Division, Chicago Convention, June 10, 1927.

[2] With Fuller and McClintock, Engineers, New York, N. Y.

[3] Superintendent of Filtration, Toledo, Ohio.

filtration plant laboratory by the regular staff, with the exception of a series of special tests carried out on the ground by the chemist of the Defiance waterworks. The main purpose of the laboratory studies was to determine by the usual physical, chemical and bacterial tests the relative suitability of the waters examined for water supply purposes. Incidental, however, to the main objective, certain studies were carried out on phenols to learn if possible the relative amounts present and their probable effect. This paper will not attempt to deal with the main phases of the water survey as outlined above, but will be confined to the local experience with detecting and estimating phenols in a total of 556 samples from different sources. Whatever conclusions may be drawn from the data, it is hoped that the results may be useful to other waterworks chemists who may have to deal with similar problems.

EARLIER DETERMINATIONS OF PHENOLS

The effects of phenols from coal tar wastes or the wastes of other destructive distillation processes upon water supply are well recognized and need not be discussed here. In the various studies which have been conducted elsewhere on phenol pollution of water supplies there has been a conspicuous absence of quantitative data as to the amount of phenol encountered. In fact most investigators have concluded that the amounts of phenol causing taste and odor after chlorination were too small to be evaluated quantitatively by chemical tests, or else the tests themselves were not considered sufficiently specific or dependable to be useful.

In connection with studies of the Youngstown, Ohio, water supply, Van Arnum (1) reported certain numerical data on the raw and filtered water, using the Folin-Denis reagent after distillation. His results, which are not stated in parts per million, simply indicate observed variations in a series of 24 tests of the raw and filtered water. Unfortunately, the results are vitiated by the finding in the heavily polluted Mahoning River of other substances than phenols, such as hydrogen sulfide from slag, which gave similar color responses.

The results of Toronto studies, reported by Howard (2) comprise, so far as the writers are aware, the only definite published figures as to quantitative findings of phenol in a water supply. An unstated number of daily tests using the Folin-Denis method showed a maximum of 12 parts per billion (0.012 p.p.m.) in the raw water when polluted with industrial wastes, while the average figures for

two months were 1.73 and 2.1 parts per billion (0.00173 and 0.0021 p.p.m.) The filtration plants reduced the phenol content as shown by the tests about 50 per cent. Iodoform taste was noted in the filtered water showing a phenol content of 6 parts per billion (0.006 p.p.m.), after the application of 0.2 p.p.m. chlorine.

Howard in a later paper with Thompson (3) indicates misgivings as to the accuracy of the figures just quoted, by stating: "The determination of phenols in raw water by the distillation method was carried out for two years and actually showed a slight increase during susceptible taste periods, but we have not found the test sufficiently sensitive to use as an index to phenol pollution." They further state: "The estimation of small amounts of phenol in water is difficult and the results so unreliable that we have been compelled to confine our observations to actual taste-tests which have seldom failed." These conclusions evidently are applicable to the Fox and Gauge method, as well as to the Folin-Denis method upon which the earlier quantitative data were based.

The estimation of phenols in the great dilution in which they are capable of affecting water supplies after being chlorinated is admittedly a difficult and uncertain undertaking at the present time. This is necessarily so when one remembers that the term "phenols" is a very inclusive one, embodying a great variety of aromatic ring compounds containing one or more hydroxyl groups. Of the complex mixtures represented by polluted waters we know little except that coal distillation and similar wastes are the most prolific and potent sources of trouble to water supplies. Of the effect of sewage or other unstable organic wastes, little is known, although phenols have been demonstrated as being among the metabolic products of the animal body.

We do not intend to enter here into a discussion of the various tests which have been proposed for the detection and estimation of phenols. A comprehensive and able review of the subject has recently been made by Gibbs of the United States Hygienic Laboratory (4), who classifies the hundred or more tests found in the literature. It is hoped that the Public Health Service will carry out additional studies on this important subject so as to give much needed confirmatory data as to the merits of the several tests.

TOLEDO DETERMINATIONS OF PHENOLS

For purposes of the Toledo Water Survey, odor and taste tests were not considered except for confirmation, although their superior sensitivity is recognized. A large number of samples from various sources, had to be tested daily, some unpolluted and others known to contain appreciable amounts of phenol. A simple measuring stick was desirable by which the relative amounts of phenol could be stated and known phenol pollution traced from its point of origin.

Preliminary to the quantitative work on water samples the sensitivity of four of the better known reagents to various common phenols was tried, with results as shown in table 1.

Bromine gives an opalescence or white precipitate according to amount present; Millons gives a pink to red color; Folin-Denis gives a blue or green color; while Fox and Gauge gives a yellow to orange color.

TABLE 1

Minimum concentration of various phenols in distilled water required to give a visible reaction in a standard 50 cc. Nessler tube

Parts per million

SUBSTANCE	BROMINE	MILLON'S REAGENT	FOLIN-DENIS REAGENT	FOX AND GAUGE REAGENT
Phenol (C_6H_5OH)	26	0.2	0.02	0.01
o-Cresol	50	1.5	0.02	0.01
m-Cresol	15	0.3	0.02	0.01
p-Cresol	150	0.3	0.02	0.01
Cresylic acid mixture (35:40:25)	25	0.7	0.02	0.02
Wood creosote	80	2.0	0.02	0.02

The Fox and Gauge reagent, on account of its greater sensitivity, indicated above, and its comparative freedom from interference by other substances than phenols, was made the basis of the quantitative data herein reported. The Fox and Gauge method for tar acids originally described in the Journal of Chemical Industry (39:260 T) was used with certain modifications suggested by Furman and Kruger (in publication), as follows:

Reagents

1. Recrystallized sulfanilic acid, 1.91 grams in 250 cc. water.
2. Pure sodium nitrite, 0.85 gram in 250 cc. water.

3. Sulphuric acid, 1 part strong acid and 3 parts water.
4. Sodium hydroxide, 8 per cent solution.
5. Stock solution pure phenol, 10 grams in 1000 cc. water (standardized against bromine), 1 cc. = 10 mgm.
6. Standard solution pure phenol, 1 cc. stock solution in 1000 cc. water (freshly prepared), 1 cc. = 0.01 mgm.
7. Potassium platinic chloride, 2 grams in 100 cc. con. hydrochloric acid diluted to 1000 cc. water.

Procedure

Distil 250 cc. of the samples and collect three successive 50 cc. Nessler tubes of the distillate. To each distillate add 2.5 cc. diazotized sulfanilic acid (freshly prepared by mixing 5 volumes of sulfanilic acid solution with 1 volume sulfuric acid, adding 5 volumes sodium nitrite solution and packing in ice) and 2.5 cc. sodium hydroxide solution. Match colors at the end of exactly five minutes against permanent standards prepared by diluting platinum solution to 50 cc. as follows:

PHENOL EQUIVALENT	PLATINUM SOLUTION
mgm.	*cc.*
0.000	1.5
0.001	2.2
0.003	3.8
0.005	4.5
0.007	5.5
0.010	7.0
0.020	10.0
0.030	17.0

The sum of the milligrams in the three tubes, multiplied by 4, represents the phenols present, expressed as parts per million pure phenol (CH_6O_6H).

In the preliminary studies, the unknown colors were matched against natural standards prepared from pure phenol. Such standards deepen on standing at room temperature and it was found more convenient to use permanent platinum standards, which gave a satisfactory match within the range indicated, although difficulty was experienced in matching higher concentrations or mixtures of cresols. For samples of heavier phenol content, aliquots were taken and made up to 250 cc. with phenol-free water before distillation. Considerable care must be used to guard against contamination of glassware from previous determinations.

No difficulty was experienced in getting blanks except on certain occasions when the tap water in the laboratory from which the distilled water supply was made responded to tests for phenols.

The principal difficulty with the method has been the failure to recover the entire amount of phenols in the first three 50 cc. portions distilled. In trials with known phenols, the first distillate usually contained the bulk, the second distillate a lesser amount and the third still less. In the routine water samples, however, it was not uncommon to recover substantial amounts in the first tube and none in the two following tubes. In a few instances, none was found in the first tube, while the second or third tubes showed measurable

TABLE 2

Recovery expressed in terms of C_6H_5OH

	MILLIGRAMS TAKEN	CONCENTRATION	MILLIGRAMS RECOVERED			
			First tube	Second tube	Third tube	Total
		p.p.m.				
o-Cresol	0.001	0.004	Trace	0	0	Trace
	0.003	0.012	0.001	0	0	0.001
	0.015	0.060	0.007	0.004	0.004	0.015
	0.025	0.100	0.020	0.005	0.003	0.028
m-Cresol	0.015	0.060	0.008	0.004	0.004	0.016
	0.025	0.100	0.010	0.008	0.005	0.023
p-Cresol	0.015	0.060	0.004	0.002	0.001	0.007
	0.025	0.100	0.007	0.006	0.003	0.016
Phenol	0.015	0.060	0.005	0.004	0.004	0.013
	0.020	0.080	0.007	0.005	0.004	0.016
	0.025	0.100	0.010	0.007	0.005	0.022
Cresylic acid mixture (35:40:25 o, m, p, cresols)	0.015	0.060	0.007	0.004	0.002	0.013
	0.025	0.100	0.015	0.005	0.003	0.023

amounts. If the entire phenol content could be dependably concentrated in the first distillate, the sensitivity of the test would be increased over the figures indicated in table 1, making it capable of detecting 2.5 parts per billion (0.0025 p.p.m.) in the case of our routine test, or a smaller amount, if larger portions than 250 cc. be taken for distillation. The actual recovery of known amounts of certain pure phenols is shown in table 2.

From these data it will be noted that, in the case of pure phenol, an average of only 85 per cent was recovered in the three tubes.

Distillation could of course be continued by steam or additions of distilled water until a blank tube was obtained, but the heavy sampling programs made inadvisable such complications or the collection of larger samples. While limitation of the test to the third tube obviously fails to satisfy the requirements of a critical quantitative

TABLE 3

Amount of phenols found in water samples examined, stated in parts per billion (0.001 p.p.m.) C_6H_5OH

SAMPLING POINT	NUMBER OF TESTS	NUMBER OF TIMES PRESENT	PARTS PER BILLION		
			Average	Maximum	Minimum
Maumee River at Toledo Intake	32	16	5.0	20	0
Miami and Erie Canal at Miami	28	13	5.1	52	0
Maumee River at Turkey Foot Rock	38	19	4.6	22	0
Miami and Erie Canal at Napoleon Intake	30	24	6.3	40	0
Auglaize River below Power Company Dam	32	19	5.9	40	0
Tiffin River at Brunersburg	31	17	4.5	24	0
Blanchard River 5 miles N. Kalida	20	15	5.9	16	0
Ottawa River at Kalida	20	16	8.9	72	0
Blanchard River at Ottawa	1	1		8	8
Blanchard River at Putnam-Hancock, line	1	0		0	0
Blanchard River below Findlay	1	1		16	16
Maumee Bay at outer Harbor light	77	29	3.6	52	0
Lake Erie, 5 miles S. E. of Harbor light (3 miles off-shore)	77	30	3.7	32	0
Lake Erie, 5 miles S. E. of Harbor light (5 miles off-shore)	39	18	4.7	24	0
Lake Erie, near mouth Detroit R.	17	9	7.9	52	0
Total	444				

determination, yet this procedure was considered adequate for the local needs. In view of the greater readiness of the phenols to distil over from the water samples, it is fair to assume that the determinations represent better than 90 per cent of the total amount present.

With these limitations stated, the principal findings are shown in table 3.

PHENOLS IN INDUSTRIAL WASTES

In addition to the above results, which represent water actually used or capable of being used as a source of water supply, examination was made of the principal industrial wastes discharging into the water courses in the vicinity of Toledo. Of 20 such wastes sampled at their outlets along the Maumee River waterfront, 37 tests showed a phenol content ranging from 4 to 19,000 parts per billion with an average of 1129 (1.129 p.p.m.).

Of 11 such wastes discharging into Ten-Mile and Swan Creeks, 22 tests gave a range from 4 to 37,800 parts per billion, with an average of 7308 (7.308 p.p.m.)

Of 10 such wastes, discharging into Duck and Otter Creeks, 20 tests gave a range of 0 to 1920 parts per billion, with an average of 149 (0.149 p.p.m.)

The principal contribution of phenol pollution locally is by the coke plant of the Toledo Furnace located at the mouth of the Maumee River. Tar passed from this drain at times. Many of the other trade waste samples had distinct odors of coal tar and some contained phenols in amount sufficient to be studied by confirmatory tests. Practically all of the wastes studied are discharged into the Maumee below the Toledo intake or into Maumee Bay. Except under extraordinary circumstances they would not affect the present water supply, although their bearing on a water supply from Lake Erie would be important.

Regarding conditions on the upper Maumee and its tributaries sources of phenol waste are known to exist, as for instance, at the gas works at Defiance. The consistent showing of phenols in the Tiffin River at Brunersburg has, however, not been satisfactorily explained. No source of phenol pollution is known on this water-shed which is exclusively agricultural, although the possibility of some undiscovered pollution such as from creosote cattle dips has not been excluded by detailed examination of all the tributary streams.

AMOUNT OF PHENOLS CAUSING TASTE

In comparison with the analytical figures given in table 3 it is interesting to note the various statements as to the amount of phenol required to give a taste in chlorinated water.

In the familiar 1919 Milwaukee water works investigation, when attention was first called to the effects of coal tar wastes on chlor-

inated waters, it was stated that 2 parts per billion (0.002 p.p.m.) phenol could be detected in the water supply after sterilization with 0.22 to 0.34 p.p.m. chlorine. A later investigation by the Milwaukee Sewerage Commission indicated that ammonia condensation liquor when added to chlorinated Lake Michigan water in dilutions equivalent to 20 parts per billion (0.020 p.p.m.) of phenol gave taste.

In investigations at the Toronto filtration plant by Howard in 1921–1922 (2) the critical range for chloro-phenol taste and odor in Lake Ontario water was found between 2 and 17 parts per billion (0.002 and 0.017 p.p.m.) phenol with chlorine dosages between 0.175 and 0.40 p.p.m. Chlorine doses lower than 0.10 p.p.m. did not cause taste with phenol, while chlorine doses in excess of 0.65 p.p.m. eliminated the taste present with smaller amount of chlorine. The combination of 7 parts per billion (0.007 p.p.m.) phenol and 0.22 p.p.m. chlorine was particularly bad, both as to taste and odor. Phenol when added in concentrations of 10 to 64 parts per billion (0.010 to 0.064 p.p.m.) to water containing 0.2 p.p.m. chlorine was almost undrinkable due to the "iodoform" taste and odor.

In the Cleveland studies by Ellms, Marshall and Phillips (1) the reliability of the Fox and Gauge test was conceded for "quantities as small as 0.1 p.p.m. of cresols," but it was further remarked, "As a result of our experience with the tests described above (i.e. Folin-Denis and Fox and Gauge), we conclude that none of them is sufficiently sensitive to make them valuable in estimating tar acids in the concentration in which they occur in water supplies, and in which they give rise to objectionable taste and odor when the water is chlorinated." The Cleveland studies used cresylic acid mixture (35:40:25, o, m, p, cresol) as the unit of expression, hence the above statement may be interpreted to mean that the critical amount of phenols, expressed as cresylic acid, lies well below 100 parts per billion (0.10 p.p.m.)

In further report of the extensive Cleveland studies Ellms and Lawrence (6) state that, in distilled water, pure phenol unchlorinated could be detected to a reasonable certainty in concentrations of 40 p.p.m. though not in 20 p.p.m. By the addition of chlorine and boiling to remove excess chlorine the concentration of 200 parts per billion (0.2 p.p.m.) phenol was easily detected.

The sense of taste and smell seems to be more highly developed in England than in this country. Adams reports (5) taste and odor with phenol concentration of 0.5 to 1.0 part per billion (0.0005 to

0.001 p.p.m.) by adding pure phenol to chlorinated well water, one observer being able to detect a concentration of 0.2 part per billion (0.0002 p.p.m.). Thresh (5) found 0.2 part per billion (0.0002 p.p.m.) phenol to give taste in tap or distilled water after addition of 0.25 p.p.m. chlorine. In Houston's own experiments (5) tap water containing 1.0 part per billion (0.001 p.p.m.) was found to give the characteristic iodoform taste when treated with 0.5 p.p.m. chlorine.

In the Toledo studies it was found that pure phenol, unchlorinated, could be detected by taste in undiluted Lake Erie water in a concentration of 25 p.p.m. The three cresols or their mixture, however, gave a taste in concentrations of 0.10 to 0.30 p.p.m. After chlorination the unmistakable chloro-phenol taste was detected in a concentration of 80 parts per billion (0.080 p.p.m.) in the case of phenol,

TABLE 4

Minimum concentration of pure phenol and chlorine required to give taste in filtered Maumee River water

Parts per million

PHENOL	CHLORINE	PHENOL	CHLORINE
0.001	0.092	0.025	0.675
0.002	0.115	0.050	0.175
0.004	0.161	0.100	0.125
0.005	0.253	0.200	0.125
0.010	0.138	0.600	0.075
0.015	0.184	0.800	0.075
0.020	0.450		

and 20 parts per billion (0.020 p.p.m.) in the case of the cresols. In attempting to duplicate the Toronto taste experiments (2) by various combinations of pure phenol and chlorine added to the filtered, but unchlorinated Maumee River water, the results in table 4 were obtained.

It should be remembered that the taste referred to in the foregoing experiments represents simply the minimum detectable taste which could be differentiated from the taste of the undosed water. Identification of an unmistakable chloro-phenol or "iodoform" taste required considerably larger concentrations than indicated in table 4, the minimum being 0.020 p.p.m. phenol in combination with 0.625 p.p.m. chlorine.

Summing up the available data, it would appear that the ordinary

taste range for pure phenol in drinking water lies between 1 and 20 parts per billion (0.001 and 0.020 p.p.m.). The cresols appear to be more far reaching in their influence upon water supply than phenol itself. The extent of taste depends upon the chlorine dose as well as upon the amount and kind of phenol present. If the values just stated should be found to be generally correct, it would seem feasible to determine quantitatively phenols lying mostly within the taste range. The figures given for the latter should be used with considerable reservation for taste sensitivity is extremely variable among individuals, both qualitatively and quantitatively. In offering the results of what might be termed a "side investigation" at Toledo, it is hoped to stimulate others to a trial of quantitative methods so that the permissible limits of phenol pollution may become reasonably established.

The authors wish to give acknowledgment to A. R. Kruger, C. A. Lindsay and John Forester, Assistants in the Filtration Plant Laboratory, for their helpfulness in connection with these studies.

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DISCUSSION

F. A. Dallyn:[4] There is very little to add to Mr. Donaldson's remarks, but it does occur to me from the very wide range of suggestions it might be advisable as a laboratory technique to include in the results the water from which the tasting took place, as the sensitiveness of the palate is affected very materially by the water.

[4] Consulting Public Health Engineer, Toronto, Ontario, Can.

C. M. Baker:[5] As near as I can determine from the paper, the determination of phenol in water is rather complicated and involved, when considering the fact that phenol can be detected in such small dilutions, when the water is chlorinated. For a practical application it seems to me, especially when you want quick tests with limited laboratory detail, the methods used in the early Milwaukee investigation produce very satisfactory results. Those methods simply consisted of collecting the samples, chlorinating the water, boiling to drive off the excess chlorine and then detecting water taste or odors due to that waste.

That is a practical method that worked out successfully there. Mr. Cunliffe directed that work and in those early investigations in Milwaukee, it was demonstrated conclusively that it was the phenol waste that caused this objectionable taste.

I think Mr. Cunliffe could tell us something in regard to the work at Milwaukee that would be of practical interest.

Russell W. Cunliffe:[6] In Milwaukee we considered the efficiency of each plant which we felt was a contributing factor to the case conducted. We took a twenty-four-hour sample and determined the amount of pollution which that would stand and which would be chlorinated and produce taste. We called that "taste producing power," or T.P.P. All the findings of that method have been subsequently worked out and proved true. Outside of this taste method used on the concentrated waste we did not think it essential to determine the amount of phenol waste.

L. H. Enslow:[7] I can only see one objection to the taste method. I think it has been ably shown that all depends upon how much chlorine is put into the water. On that ground it would be better to give the conditions from day to day, just the chlorine, gas and sewage analyses, or estimating the quantitative value, or semi-quantitative value. I cannot see where these investigations can check results on such a matter.

Mr. Cunliffe:[6] This was not a river proposition. It was on the lake where there are no established currents. The taste so far as

[5]State Board of Health, Madison, Wis.

[6]Milwaukee, Wis.

[7]Chlorine Institute, Inc., New York, N. Y.

we were concerned was practically a method of concentrating on a solution of the problem. The chlorination taste is applied on effluents from the same plant with remarkable results.

Louis B. Harrison:[8] I want to call attention to the effect that sunshine has on reaction of phenol tastes. If you try to determine taste by adding chlorine to the water in which there are traces of phenol in the presence of sunshine you are very apt to miss the taste entirely, because the sun's rays facilitate the action which a small amount of chlorine may have in connection with phenol so that the taste disappears immediately.

F. W. Mohlman:[9] I have been carrying out a few research tests on tastes, especially as founded on varying amounts of organic matter. I have found that iodine enters into the taste matter as well as other things already mentioned.

Wellington Donaldson:[2] In connection with Mr. Cunliffe's remarks it might be well to explain a little. We were striving to do two different things at Milwaukee and Toledo. At Milwaukee there were actual tastes in the water and it was a question of tracing them out with methods which would give results comparable with the consumer's perception.

At Toledo during this investigation it was not a question of taste usual in the water supply. It was a question of finding some numerical value for various waters collected from different points, rivers and lakes and wastes where a very wide range would be covered and obviously taste and odor methods would not be useful to us in that connection.

It occurs to me to suggest also that one possible defect about the chlorination and boiling method, one valuable factor besides those which Mr. Enslow names, is the time of boiling. I think that has to be taken account of. If the quantitative test has been made you will have to standardize the boiling time.

Mr. Mohlman:[9] I would like to ask the gentleman from Milwaukee how many samples he could taste in one day? We found in Chicago that a man could taste just so much a day. When you taste

[8] Bay City Water Works, Bay City, Mich.
[9] Chief Chemist, Sanitary District of Chicago, Chicago, Ill.

two or three samples in a row and go back to your first taste, it will be different. There is a limit to the number of samples that a man can taste and test accurately in one day.

Mr. Cunliffe:[6] We tasted as many as 200 and sometimes as high as 500 samples in one day. I am sorry we have not our charts here so we could show you the results. We classify the tastes in that way. We use three values, a very slight taste, strong taste and very strong taste. The taste factor is a peculiar thing. We have recorded our results and it was remarkable how different observers were on these different things, but at the end of the day we think our tasters were about in as good shape as they were in the beginning.

The plant on the Menominee River was about three miles out. We had some waste coming in from the Milwaukee River north and then we had also a source of taste from the coke plants down on the mouth of the river.

Dana E. Kepner:[10] We have found in Colorado that by taking a drink of pure water, preferably distilled, and then taking the test sample we are able to get a very much better idea of the sample. We have also found that men who do not smoke have more sensitive tastes than the ones who do.

Carl J. Lauter:[11] I have found the same thing in Washington. Personally I could taste it very well while some of the men could not detect it easily in the creosote chlorinated water.

William C. Lawrence:[12] I want to compliment the authors on the good paper they produced, but I wondered how far we would have gotten in Milwaukee in detecting and curing the situation in the way of industrial wastes. We had nothing else to fall back on except taste and it certainly cleaned up a big problem. Later on we did this technical work. Of course, we did not have the sensitive taste that they have developed in England, but we did clear up the situation.

[10] Director, Division of Sanitation, State Department of Health, Denver, Colo.
[11] Chief Chemist, Filtration Plant, Washington, D. C.
[12] Superintendent, Filtration and Sewage Disposal, Cleveland Ohio.

Chairman Howard: Gentlemen, our work in Toronto has extended through the past twelve years and possibly has been as extensive as any work being carried on on the North American continent.

Mr. Lawrence mentioned a point which was in my mind, namely, that we all realize and know we have tastes, but we do not know in many cases from where the taste is coming. The tendency, as soon as taste occurs in the water supply, is to say it is chloro-phenol. In a large number of cases there is no evidence supporting the phenol theory at all. Where we have direct industrial phenol, where we have phenol discharges, creosote discharges or even industrial discharges of non-phenol content, the taste is perfectly clear, but there are far more cases which are obscured in the light of our present knowledge as to what is the definite cause of taste.

Mr. Dallyn raised a very important point bearing on the temperature. In most cases the worst taste is recorded in waters under the temperature about 45° Fahrenheit. I say in most cases. There are many cases where tastes occur at all temperatures, but the worst taste is reported from cold water. One theory is that the biological activity in the water as the water warms up destroys the phenols, thereby reducing the amount of taste noticed.

The preliminary work carried out in Milwaukee in 1919 substantiated that fact. We have a very marked seasonal variation, and to date no one appears to be quite sure what the cause is. It is a matter that I would like to touch on later regarding the treatment under seasonal conditions. We can get phenols directly as the result of decomposition, decomposing sewage and organic matter, which form small amounts of phenol which may react in the water in the presence of chlorine.

There is such a large combination of conditions, in spite of the great amount of work that has been done up to the present time, that we really are a little in the dark as to the cause of taste under many conditions. The work Mr. Donaldson carried out during the past four or five years has been very exhaustive and has brought forth much material. Yet the same technique carried out in other parts of the country has fallen down. It has fallen down quite badly for a series of reasons. The fact that the amount of applied phenol cannot be recovered in water has been observed in several places. We in Toronto have been able to recover about twenty to forty per cent of the amount applied in water we know perfectly

well did not contain phenol. In other words, the colorimetric tests indicate more phenol present than was actually in solution. This test was not a success and in fact failed in waters containing other agents which react to the treatment.

We found some of the tests were not consistent and contained acids and when we followed the work found alkaline wastes are less liable to taste. The work that has been ultimately limited to taste apparently is the one method which is receiving the most support in this meeting today.

RECENT ADVANCES IN CONTROLLING CHLORO-TASTES AND ALGAE DEVELOPMENT[1]

By L. H. Enslow[2]

It is once more the good fortune of American water works officials to profit from the experiences and researches of the English. Years ago, Sir Alexander Houston blazed the trail in chlorination and pre-chlorination of water on a large scale. This same investigator, justly termed "The Father of Chlorination of Water," has also shown, through his untiring researches, methods of reducing considerably and perhaps eliminating entirely the undesirable features of chlorination. Another Englishman, B. A. Adams (1) has succeeded likewise in combating the production of foul tastes sometimes present in chlorinated waters. To Houston (2) is due the major credit for progress in this direction. His statement of some years past that chlorine boldness rather than chlorine temerity will solve the problem of chlorine by-product taste prevention is rapidly proving to be well founded.

There are several types of organic matter which have the power of producing foul tastes and odors when in combination with chlorine. The simplest and probably the most common of these are the end-products of decay from vegetable and animal matter, including the essential oils liberated from algae growths. The more serious and less readily controlled organic pollution which causes taste with chlorine is that having its origin in the phenol and cresol group of compounds. Such polluting material enters the water supply in the form of industrial wastes or from domestic sewers, into which is discharged the waste from industrial plants or from hospitals in which phenolic disinfectants are employed.

In the first instance, the foul by-products may usually be destroyed by increasing the chlorine application and doing nothing further, except perhaps, subsequently storing the water for a few hours, or the super-chlorination process may be followed with aeration after a

[1] Presented before the Chicago Convention, June 10, 1927.

[2] Sanitary Engineer, The Chlorine Institute, Inc., New York, N. Y.

shorter period of contact. With the biological type of trouble-producing substances, super-chlorination of the water at some point ahead of the filters appears in certain instances to be all that is required. If necessary, a small dosage of chlorine may also be applied to the plant effluent for additional safety.

In the second instance, where the trouble may be termed chemical in origin, a more drastic super-chlorination, a period of contact, and finally dechlorination are required. For certain conditions, the addition of ammonia previous to chlorine application may reduce or eliminate chloro by-product tastes.

Chloro by-product tastes have resulted also from free chlorine in the water reacting with pipe coating material or other deposits within the mains, standpipes or tanks, to produce the foul taste in the distribution system, but not at the chlorinating plant. In such cases the only practicable remedy appears to be that of treating the water so as to prevent residual chlorine in the water when delivered to the distribution system. Pre-chlorination alone; use of ammonia in conjunction with subsequent or pre-chlorination; storage of the chlorinated water for sufficient periods; or the lowering of the pH value of the water, which insures a more rapid dissipation of the residual chlorine, are suggested procedures. In the last instance re-carbonation of softened waters or adjustment of chemical dosages applied for coagulation purposes and of the chlorine applied to the filter effluent appear feasible. A subsequent period of contact to allow fairly complete dissipation of excess chlorine before the water is delivered to the mains is also desirable.

SUPER-CHLORINATION AND DOUBLE CHLORINATION

At the White Rock filtration plant at Dallas, Texas, Bakke (3) has for the past three seasons successfully carried out super-chlorination of the raw water and subsequent chlorination of the filter effluent. This plan was practiced for destroying chloro products formed between the decomposition products from vegetable matter and algae in the raw lake water and the coagulation basins ahead of the filters. A rather high dosage of chlorine is applied to the filtered water, which at all times results in a residual chlorine content of 0.3 p.p.m. or more in the water entering the clear well of large capacity. No complaints from excess chlorine or by-product tastes are heard from consumers during such operating conditions, whereas, prior to such drastic chlorination, complaints were many and continuous.

The average dosage of chlorine applied to the raw water is sufficient to produce 0.35 p.p.m. residual at the entrance to the coagulation basins.

DOUBLE CHLORINATION AND pH ADJUSTMENT

At the Turtle Creek plant at Dallas, Texas, where iron sulphate and lime are employed to coagulate and soften the supply ahead of the filters, Bakke employs double chlorination. The filtered water is chlorinated as it enters a large open clear-water storage basin and again as it leaves the plant for delivery directly into the distribution system. Investigation disclosed that such tastes were being formed within the mains and never in the clear-water storage basin at the plant. The solution of the difficulty was found in the adjustment of the chemicals applied to the raw water. Lowering of the pH value of the filtered water prior to chlorination resulted in the elimination of stabilized available chlorine compounds produced when chlorine was added to the water with a higher pH value. The end result was an increased dissipation of the available chlorine. This meant that residual chlorine in the water reaching the offending sections of the distribution system and dead ends was absent or else was insufficient to produce the foul tasting by-products within the mains. As will later be shown in recounting the experiences of McAmis at Greeneville, Tenn., it is probable that an application of ammonia to the water ahead of chlorination would have solved the difficulties equally as well as regulation of the chemical dosage causing more rapid dissipation of the chlorine. The latter effect is probably a result of eliminating either the formation or the stabilization of hypochlorites in the water.

Bakke (3) points out that, had re-carbonation of the settled water been possible, this process would have been employed rather than the reducing of the lime and increasing of sulphate of iron. Prior to adjustment of pH value of the water ahead of chlorination, super-chlorination without dechlorination had been tried without success.

SUPER-CHLORINATION AND DECHLORINATION

For the past several years Norman J. Howard, at the Toronto, Ontario, filter plants has been conducting laboratory scale experiments in connection with the chlorination of waters containing phenols, cresols or their derivatives. This work had been conducted simultaneously with that of Sir Alexander Houston. As a result of

the favorable outcome of the work of Houston, which agreed with the observations made by Howard, Howard and Thompson (4) in 1926 carried out a thorough investigation into the actual quantities of chlorine required and the contact period necessary to destroy the various phenols or cresols. Complete data as to the quantity of chlorine required for phenol destruction by super-chlorination followed by the contact period available at the Toronto plant and the quantity of sulphur dioxide later required to reduce the excess chlorine to that desirable before discharging the water to the mains was presented to the city authorities. Adoption of the process was authorized in the late summer of 1926. It proved to be immediately effective.

In the application the entire plant output delivered to the city (70 m.g.d.) was from the first super-chlorinated. The dosage of chlorine applied to the effluent of the filters was between 0.75 and 1.25 p.p.m. followed by an average period of contact of one and one-fourth hours. Sulphur dioxide (0.28 to 0.62 p.p.m.) was next applied to the super-chlorinated effluent at the pump station delivering to the mains. The application of the sulphur dioxide gas was made from cylinders of liquid sulphur dioxide connected to Wallace and Tiernan vacuum type chlorinators which were fitted with special orifices and other parts where necessary. These machines have performed satisfactorily and are operated by an attendant who adjusts the dosage so as to barely destroy all residual chlorine in the water delivered into the mains.

Howard reports that, whereas the theoretical relationship between the sulphur dioxide necessary to destroy a given excess of chlorine is 0.9 pound of sulphur dioxide for 1 pound of chlorine, it appears in actual practice that 1 part of chlorine requires 1.12 parts of sulphur dioxide, i.e., a quantity of 25 per cent in excess of the theoretical. Under certain conditions as much as 50 per cent in excess was required. During heavy rates of discharge the pressure in the sulphur dioxide cylinders was difficult to maintain unless a temperature above 80°F. was provided, or unless a relatively large number of cylinders were connected to each machine. Recently steam coils have been placed between the cylinders to facilitate rapid delivery of the gas.

A small portion of the Toronto supply could not be super-chlorinated and de-chlorinated. During the first period of super-chlorination the main supply developed no taste, whereas that not super-

chlorinated was noticeably foul tasting. During a short period after beginning super-chlorination the sulphur dioxide supply was exhausted and with the discontinuance of super-chlorination the foul taste returned to the main supply.

Super-chlorination and dechlorination have been applied to 70 m.g.d. flow at Toronto for a total of eighty-four days. It was discontinued December 8, 1926, because of lack of necessary appropriation. Immediately following discontinuance foul tastes developed and persisted for a few days until the wind direction changed and the pollution was driven from the vicinity of the raw water intake. Since then complaints have been intermittent, depending upon the meteorological conditions.

Howard recently reports that a greater chlorine dosage is required at times when the water temperature drops below 42°F. Although 1.25 p.p.m. appeared sufficient under summer and fall conditions, the cold water during winter requires as much as 2.00 p.p.m. to be effective with the contact period available, viz., one and one-fourth hours. This situation is believed to be a result of lessened biological activity in the raw water in cold weather and therefore a greater concentration of undestroyed phenols with which super-chlorination must cope.

The City Council has sanctioned the return to super-chlorination and dechlorination at Toronto and has appropriated the necessary funds for equipment of increased capacity. Within a short time the process of super-chlorination and dechlorination will be in use again. The estimated cost even with the heavy winter dosages will amount approximately to $32,000 per year with continuous application. The cost of treatment will average something less than $1.75 per million gallons. The use of chlorine in ton containers at the Toronto plant would reduce the cost of super-chlorination materially.

Harrison (5) who has conducted laboratory experiments at Bay City, Michigan, has confirmed the results reported by Howard and Thompson in their preliminary work at Toronto. Harrison finds also that it is imperative to insure a sufficiently high residual chlorine (never less than 0.6 p.p.m.) and thereafter a contact period of two hours prior to dechlorination. Harrison finds, as Howard has, that a gradual increase of chlorine applied to water containing phenols will produce a foul taste, which upon further increase of chlorine will be lessened and finally will disappear. Further increases again result in re-appearance of foul tastes and finally super-chlorination

effectively and permanently destroys the taste after the necessary contact period has been allowed.

THE AMMONIA-CHLORINE PROCESS

In Canada, Race (6), for sterilization purposes, successfully employed a mixture of hypochlorite solution and weak ammonia water. Improved taste of the water so treated was secured at the expense of rapid sterilization. Thresh (7) also reports the successful use of this method in England at a water works using river water. Major Harold (8) of the British Army has succeeded in producing chloramines from chlorine water and ammonia water and in obtaining a patent on the process of first producing chloramines from chlorine gas and ammonia solution and thereafter applying such solution to the water, etc.

In England both Sir Alexander Houston (1, 10) and B. A. Adams (2, 9) reported very effective results obtained in chloro-taste prevention, when applying ammonia in conjunction with liquid chlorine. Houston applies the ammonia to the water prior to the chlorine application. Adams prefers to mix the ammonia solution and chlorine solution just prior to admitting the mixture to the water. Houston refers to the latter method as that of Harold (8) and, after comparison of the two methods experimentally, points out the various advantages and economic aspects of each method. On the whole, Houston favors the application of the ammonia to the water at a point ahead of the point of chlorine application. Comparing the use of permanganate ahead of chlorine application with the ammonia-chlorine combination the results are in favor of the latter method. Houston points out that application of approximately 0.25 p.p.m. of ammonia (NH_3) is sufficient in most cases to *prevent* taste production when the chlorine is later applied. On the other hand, *ammonia added after chlorination will not remove the chloro-taste* once it has been produced.

Adams (9) claims greater efficiency from the Harold process and prefers gaseous ammonia to ammonium salts in any event.

At Greeneville, Tenn., during the past several years complaints of "iodoformish" chloro-tastes have been frequent during the summer months. The water supply is derived from a limestone spring not subject to pollution by phenol wastes or other industrial wastes. This normally clear, but hard, spring water is softened and clarified with lime and iron sulphate, and thereafter filtered. To eliminate

the intermittent chloro-tastes J. W. McAmis, superintendent of the water works, attempted to super-chlorinate without subsequently dechlorinating and later tried double chlorination also, without material success in either case. In double chlorination a primary dosage was applied to the raw water and the secondary dosage applied to the water leaving the clear well to enter the distribution system.

It is interesting to note in the report of McAmis (11) that the chloro-tastes never developed in samples collected at the softening plant and even in the distribution system in which the tastes developed intermittently. The water temperature range during taste production always was found to be between 17° and 23°C. He further points out that a possibility exists wherein the pipe coating material or foreign substances within the service tanks or mains might be the source of the taste production.

In any event, not having attained success in various other attempts at taste eradication, McAmis, familiar with the ammonia-chlorine combinations used by Houston with success, attempted the use of ammonia water prior to the chlorine application. This marks the first attempt on a plant scale with this process in America.

In the first trial ammonia water was applied to the raw water prior to application of softening chemicals. The chlorine was applied, as previously, at a point about half way of the mixing chamber and after the softening chemicals had begun to coagulate in the water. The process was an immediate success and chloro tastes entirely disappeared from the distribution system. Discontinuance of ammonia application resulted in the re-appearance of chloro-tastes.

Having had undeniable success with this scheme, the ammonia application was continued to the raw water, but the point of chlorine application was changed to the filter effluent. The tastes were not formed under the latter operating procedure and therefore the chlorine application to the filter effluent continues to date. McAmis (11) points out, however, that the lagging of efficiency of sterilization was observed when employing the ammonia-chlorine treatment and thus a longer period of contact is required than otherwise. It would appear, therefore, that with absence of sufficient contact elsewhere the chlorine should be applied at the inlet end of the coagulating basin.

McAmis also calls attention to the very slow development of maximum color when ortho-tolidin is added to the ammoniated-chlorinated water, presumably containing chloramines rather than free chlorine or hypochlorites.

METHOD OF PREPARING AND FEEDING AMMONIA

The high solubility of ammonia gas in cool water enables one to prepare the ammonia solution quickly with simple equipment. A mixing device and gas diffusor are not essential in the dissolving tank but may prove advantageous. The ammonia water is fed from an ordinary orifice box.

AMMONIA REQUIRED

At Greeneville, Tenn., 0.25 p.p.m. (2.08 pounds per million gallons) ammonia (NH_3) apparently gave satisfactory results at all times and at times even lower dosages also proved effective. Increased dosages failed to impart any taste to the finished water.

A tank of 100 gallons solution capacity should serve when applying ammonia at the rate of 0.25 p.p.m. to water passing at the rate of 10 m.g.d. for seven hours. The strength of solution prepared would be 0.75 per cent of NH_3 by weight, i.e., 6.25 pounds of ammonia gas (NH_3) in 100 gallons of water. If loss of ammonia is noticeable the solution strength should be reduced and increased tank capacity provided. The ammonia solution should be delivered from the tank into the water with a minimum of free fall or splash.

COST OF TREATMENT

Houston (2) reports cost of chemicals in the ammonia-chlorine process to be 41 cents per million gallons of water treated.

McAmis (11), operating on a much smaller scale and with higher cost of chemicals, reports the cost to be about 60 cents per million gallons treated.

PREVENTION OR RETARDATION OF ALGAE DEVELOPMENT

Within the past year attention has been directed toward the use of chlorine for the dual purpose of bacteria reduction and algae growth prevention when applied to the raw water entering coagulation basins, service reservoirs or swimming pools. For some years prechlorination has been effectively used in several places to increase the efficiency of coagulation, reduction of wash-water and biological growths in the filter beds and underdrains. Cohen (12) reports on the successful application of chlorine to reduce and thereafter retard algae growths in settling basins at Lufkin, Texas, and in a service reservoir at Mexia, Texas. The results secured so far indicate that

certain forms of algae are more resistant to copper sulphate than to chlorine and, further, that in certain instances the use of copper-sulphate will prove more expensive. It would appear that application of chlorine to insure a residual of 0.5 p.p.m. will effectively kill most forms of algae so far encountered.

At Mexia, Texas, R. F. Morgan, superintendent of water works, has apparently improved the process of algae control with chlorine by application of hydrated lime simultaneously with the chlorine. The result obtained appears to be a retardation of residual chlorine dissipation in the service reservoir and thus a more lasting effect from the chlorine application is secured. The dosages used on this clear water are approximately 8 pounds of hydrated lime and 6 pounds of liquid chlorine per million gallons treated. Certain forms of algae resistant to 15 p.p.m. of copper sulphate were by this process eliminated.

At Texarkana, Texas, it is reported that chlorine has been successfully used in an outdoor swimming pool for the sole purpose of destroying algae growths and retardation of subsequent algae development.

At Lufkin, and Mexia, Texas, in 1926, considerable economy has resulted by reducing the frequency of basin cleaning at the former and copper sulphate additions and reservoir cleaning at the latter named place. Further tests at Mexia during the summer of 1927 will serve to check the results obtained in 1926.

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DISCUSSION

C. R. Cox:[3] Mr. Enslow's review of the problems of preventing tastes in chlorinated water summarizes the latest developments in this interesting field. The purification of water, is becoming a more complex problem as the raw water becomes more heavily polluted and because the public is demanding water which is physically attractive as well as safe from a sanitary standpoint. In fact, the prevention of tastes is attracting as much attention as that heretofore given to the problems of producing bacteriologically pure water.

The prevention of pollution of water supplies by taste producing substances should be given precedent over the treatment of waters to remove such material. Such pollution inevitably occurs at times, however, and then taste removal is a serious problem. It may be of interest, therefore, to review briefly the experiences at two water purification plants in New York State where phenol taste problems have arisen, because a phenol waste disposal plant was placed in use at a coke plant in one instance to prevent such tastes from developing, and potassium permanganate treatment has been utilized at one of the water purification plants to destroy such taste producing substances present in the raw water. Both of these plants are under the direction of James M. Caird, Chemist, of Troy, New York.

The small mechanical filtration plant at Rensselaer, New York, treats heavily polluted Hudson River water. Chlorine is applied at two points, namely, from 0.75 to 1.5 p.p.m. to the raw water, and from 0.25 to 1.0 p.p.m. to the filtered water. These doses are based upon the destruction of the large number of B. coli present in the raw water, and not upon the maintenance of any definite quantity of residual chlorine in the filtered water, although such residual is obviously determined from time to time as a secondary guide. Smaller

[3] Assistant Engineer, State Department of Health, Albany, N. Y.

doses of chlorine would be feasible if the period of sedimentation were greater than the one hour available, because this would provide longer periods of contact for the action of the raw water chlorine dose, which would thus disappear to a large extent before the water passes through the filters.

Oxygen consumed values of this raw water vary from 7.0 to 25.0 p.p.m. Notwithstanding this high organic content, the final effluent has a satisfactory taste at many times, provided the residual chlorine is removed by the use of some anti-chlor, such as sodium thiosulphate. Independent of the distinctive chlorine taste, there is a bitter, musty taste in the filter effluent at times which disappears when an anti-chlor is added to the water. This would indicate that this taste is due to unstable reaction product of chlorine and organic matter, such as the sulphite pulp wastes present in the river water.

Notwithstanding the prevalence of the true residual chlorine taste and this other bitter taste in the filter effluent at times in the past, serious complaints were not received from the consumers until the fall of 1925 when the Hudson Valley Coke and Products Corporation constructed a large coke oven and gas plant in South Troy about 5 miles above the intake of the Rensselaer water supply. This corporation installed, at the instigation of the State Department of Health, a phenol recovery plant whereby it was hoped to prevent the discharge of phenol into the river. A similar plant is in use at the Iroquois Coke Plant at Buffalo, New York and at a coke plant in Lorain, Ohio. These plants have been described in the literature, but it may be of interest to give the essential details at this point.

Ammonia liquors from the primary coolers of the coke plant contain practically all of the phenol wastes washed from the gas. These liquids are pumped through benzol scrubbers where the phenol is absorbed by the benzol. The benzol is then pumped through water scrubbers to remove carbon dioxide and then through caustic soda scrubbers where sodium phenolate is produced. The de-phenolated benzol is then pumped back to the benzol scrubbers and re-used. The sodium phenolate is treated with sulphuric acid whereupon sodium sulphate and phenol are formed. The efficiency of the plant varies from 80 to 98 per cent, although at most times the efficiency is between 90 and 95 per cent. The coke plant produces from 200 to 300 pounds of phenol per day when the production is from 1200 to 1500 tons of coke, so that from 10 to 30 pounds of phenol remain in the ammonia liquors discharged into the river each day.

Formerly these ammonia liquors were discharged onto incandescent coke where approximately 50 per cent of the phenol was evaporated. Odors due to ammonia were claimed to be produced by this procedure so that the piping system was modified and the ammonia liquors were discharged directly into the Hudson River. This intensified the tastes at Rensselaer so that the discharge has been limited to the period between 6 a. m. and noon, in order that most of the wastes would pass down the Hudson river below the intake before the filtration plant at Rensselaer is started each day at 5 p.m. This modification has improved the quality of the water pumped through the intake.

Notwithstanding the removal of most of the phenols from these coke plant wastes and the rather large dilution obtaining in the Hudson river, obnoxious chlorophenol tastes have occurred in the Rensselaer water supply at frequent intervals, especially during the winter of 1926–1927, during periods of relatively low stream flow, and before the discharge of the wastes was regulated to suit the operating schedule at the filtration plant. Several accidents have occurred whereby large quantities of phenol have been released into the river, and for over a month in 1926, the phenol recovery plant had to be shut down for repairs and remodeling. Due to this situation, the coke plant chemists are carrying on research work with a view to improving the efficiency of their phenol recovery plant.

The practice of super-chlorination to destroy chlorophenol tastes, such as at Toronto, Canada, cannot be utilized at Rensselaer, New York, due to the physical limitations of the filter plant. In the meantime, the spring run-off has supplied sufficient diluting water to prevent tastes from being noticeable. It is possible that the tastes may be prevented in the future by the ammonia method as practiced at Greeneville, Tenn. or by the potassium permanganate method first utilized by Houston in London and now being used at Rochester, New York.

The Rochester and Lake Ontario Water Company maintains a pressure mechanical filtration plant which treats Lake Ontario water. The intake is located about 4000 feet from shore at a point about one mile west of the mouth of the Genesee river, on which the city of Rochester is located. At most times relatively clear Lake Ontario water, with a low organic content, is pumped through the intake, but, when the winds are easterly, the polluted river water is driven towards the intake. Marked modification in the character of the lake water appears at such times so that effective chlorination

is rendered more difficult and obnoxious tastes are produced when chlorine is added to the water. It is a well known fact that large quantities of chlorine cannot be added to water from the Great Lakes without the production of tastes due to residual chlorine. It is fortunately possible, however, to chlorinate such water with relatively small doses of chlorine. Thus the average dose of chlorine for 1926 at the Rochester plant was about 0.3 p.p.m. This dose is applied at two points, to the raw water, where the dose varies between 0.15 and 0.56 p.p.m. and to the filtered water where the dose varies between 0.036 and 0.077 p.p.m. These very small doses of chlorine at most times lead to the presence of a slight residual in the treated water and satisfactory bacterial removal has resulted. During periods of easterly winds, however, it is necessary to increase the raw water dose to 0.9 p.p.m. Even then no residual chlorine was present in the filtered water and obnoxious chlorophenol tastes were developed. It was known that industrial wastes from the Eastmen Kodak plant and the gas plant of the Rochester Gas and Electric Company were discharged into the river. As these wastes could not be treated at once, potassium permanganate was utilized at the filtration plant in an endeavor to destroy the taste producing substances.

After some preliminary studies it was found that satisfactory results could be secured by such treatment when potassium permanganate solution was added to the raw water in relatively small quantities. This chemical is not added at all times, but the absence of the usual amount of residual chlorine in the filtered water is used as a criterion for the addition of the potassium permanganate. In other words, when normal lake water is passing through the intake and small doses of chlorine produce satisfactory residuals, no potassium permanganate is utilized, but during periods of easterly winds the quantity of organic matter present in the raw water increases, the residual chlorine disappears and the potassium permanganate treatment is utilized. It has been found possible to destroy the taste producing substances by the addition of from 1.0 to 1.6 pounds of potassium permanganate per million gallons of water treated. The use of this chemical enables the original chlorine dose to be utilized without the production of chlorophenol tastes and with the maintenance of the desirable trace of residual chlorine in the filtered water. To date very satisfactory results have been secured. It should be remembered, however, that manganese is an undesirable constituent in water when present in quantities greater than about 0.3 p.p.m.,

due to the fact that articles of clothing are stained by the manganese. As the effective doses are low, this practical objection should not be important, although the use of other oxidizing substances should be investigated. The organic matter in the water reacts with the permanganate and thus colors due to this compound are not formed.

Commercial potassium permanganate purchased in large quantities may be obtained at about 18 to 25 cents a pound, depending upon the quality of the material and the quantity purchased.

About 20,000 gallons of ammonia liquors are produced at the gas plant of the Rochester Gas and Electric Company each day. These liquors contain about 350 pounds of phenol, so presumably this phenol was the cause of the obnoxious tastes noted above. Studies are being made by the officials of the city of Rochester, in coöperation with the officials of the gas company, relative to the possibility of discharging these wastes into the city sewers without the biological processes at the sewage disposal plant being affected thereby.

The wastes from the Eastman Kodak plant contain only small quantities of phenol-like bodies, but relatively large quantities of organic wastes. Studies are being conducted relative to the installation of an organic waste disposal plant at this factory. This plant should eliminate marked changes in the chlorine demand of the lake water and should thus improve the efficiency of chlorination.

Paul Hansen:[4] I would like to mention that Mr. Enslow did not speak at any length on the use of chlorine in the conditioning of the sand bed. There is an opportunity for extending the use of chlorine. One of our great difficulties in the operation of filter plants using lake water is short run troubles, clogging of beds, mud balls, drawing of the sands away from the sides of the filters, etc. It may be possible with the skillful and proper application of chlorine, together with proper analytical control, principally through the microscopic examination of sand grains as described by Mr. Baylis, to have a means of conditioning our beds as a routine matter of filter operation.

I would like to say a word about the reason why in some places the effect of phenol tastes is more pronounced in winter than in summer. Many of these phenol wastes are discharged from the industries at a more or less high temperature. In the winter these wastes coming close to the surface of the water are cooled down to a point of maxi-

[4] Of Pearse, Greeley and Hansen, Consulting Engineers, Chicago, Ill.

mum density and sink. In the summer they continue to float in a warm condition on the top of the water and do not go down and thus do not reach the intakes. This was very clearly observed at Marquette, Michigan, where the coater supply is affected by phenol tastes resulting from the discharge of wastes from a charcoal by-products plant.

I trust that Mr. Enslow will make papers of this sort and character an annual affair. There is nobody in the country who is in a better position to keep track of the developments in the use of chlorine as applied to the treatment of water than is Mr. Enslow. We would appreciate an annual summary of the status of the art and practice of using chlorine.

HOWARD E. MOSES:[5] To my mind, there are at least two cases where pre-chlorination is of advantage. First, where a heavy pollution load is on the filters and the dose can be split and possibly avoid the after taste from chlorination where it is all applied after filtration. The other is where the filtered water product goes directly to the consumers and all chlorine is added in the clear water. To keep down the tastes and odors under these conditions is very difficult. There are various degrees between those two.

Several plants illustrate this. There is a large plant on the lower Delaware River that is very heavily loaded on account of the stream being grossly contaminated with both sewage and industrial waste. They started pre-chlorination, splitting the dose, and introduced the preliminary dose at about the same time the coagulation in the waters began. The water is chlorinated again before it goes into the system. In this instance it is pumped directly to the main. This plant which serves 70,000 people seems to operate successfully without causing complaints.

There is another plant on the Schuylkill River, where pre-chlorination has been started in the last few years. This water is not as heavily polluted as that of the Delaware River.

As a contrast, I know two plants that are on upland streams. On one of them, a short time ago, a distinct musty odor developed. As a matter of experiment pre-chlorination was tried. It worked so well that they have been continuing it every since. The same company has another plant where they pre-chlorinate. It is interesting

[5] Assistant Chief Engineer, State Department of Health, Harrisburg, Pa.

to note in this connection that they treated it this year also with copper sulphate.

We had at one plant two instances of trouble from phenolic compounds caused by the draining of roads that had been freshly oiled by the Highway Department. There is not much that can be done. In this particular instance the water company is keeping a very careful watch on the road oiling schedule of the Highway Department so as to be on the lookout for any further trouble of that sort.

Malcolm Pirine:[6] May I suggest something that might be advantageous in a number of plants for conditioning the sand beds in the treatment of wash water. We are finding the condition of wash water which may help to remove continually the tendency to form a film on sand.

In one of our plants we have used a relatively hard well water for wash water. Possibly there are other locations where that might be done. I have not gone far enough with it yet to determine just how effective that is in cleaning off the film that forms on sand grains. We do not want to treat the water going through the filters, because we want that film to work just as hard as it will in removing all impurities in the passing water.

The plant that I have in mind is one at Rahway, New Jersey, where they were having very bad troubles with odors. It was apparent that it was partly due to filters which were not working properly. It was a pressure filter. The water was coagulated and pumped to a standpipe. The standpipe acted as a coagulating basin and the water passed back through the filters into the mains, receiving chlorine directly in the mains as it left the filter plant. There was a substitute plant to be used during excess turbidities of the river water that consisted of a coagulating basin. The water from that passed through the pressure filters and up to a clear well. The water from the clear well was pumped into the distribution system, the standpipe acting as a pure water standpipe.

The development of super-chlorination in getting rid of industrial tastes, from phenols which were coming down from the river from a chemical plant at a little distance above the intake, gave us the idea of using exactly the structures that were there in revamping that plant and simply adding to it. We increased the coagulating

[6] Consulting Engineer, New York, N. Y.

basin and introduced aeration. The water flows from the coagulating basin onto the top of the gravel filter and receives the chlorine dose as it enters the clear well. There is a retention period of several hours in the clear well. We had to use that pressure filter house for something and it worked out very well, considering possibilities of future treatment, by leading the water from the clear well to the aerating system in the old pressure filter house.

The water flows to fixed nozzles with a variable nozzle which is controlled by a float, maintaining a definite head of water on the suction of the pumps.

If the chemical industry gets out of the control of the Board of Health and discharges a lot of stuff into that water which requires super-chlorination to overcome the tastes produced by it, they can apply all the chlorine they want, which has been satisfactory to Mr. Enslow. If anybody interested in the use of chlorine will keep away from the windows and the aerator or air house, most of the excess would go off there. We have found by experiment that excess chlorine would go off in the spray of the aerator after the water was properly cleaned up. And then it will not be necessary to use as much sulphur dioxide, which is an expensive chemical, in finally dechlorinating the water as it goes into the mains.

J. W. McAmis:[7] There is nothing I could add to what has already been said, except in the nature of second hand material. I would like to add my homage to Sir Alexander Houston and some of the others that have pioneered in chlorine and taste treatment.

There is only one thing that seems to me ought to be impressed on water works people and that is the ease and simplicity of the ammonia treatment we have been using in Greenville. As my operator said, "it is just like falling off a log, nothing to it, works very nicely, and if you get a little too much you have no trouble, it makes no taste at all in the water."

Louis B. Harrison:[8] In my experience I have found that, in order to destroy the phenol tastes, the reaction period is of great importance. A minimum of two hours is required at Bay City. After the chlorine excess has been destroyed, no matter how long the sample stands in the laboratory, the taste does not reappear. In all these cases the minimum reaction period must be determined.

[7] Superintendent, Water Works, Greenville, Tenn.

[8] Water Works, Bay City, Mich.

I have remarked before that violet rays tend to alter the reaction. We ought to determine what effect violet rays in combination with super-chlorination will have. I have not been able to perform any experiments with ultra-violet rays, but I am going to do so in the future.

I have also experimented in a plant on super-chlorination of musty tastes. I have met with great failure and disappointment. Whereas the super-chlorination did remove the musty taste, it produced in its stead a sort of weedy taste that was worse than the original musty one.

Floyd W. Mohlman:[9] Mr. Enslow referred to some laboratory tests that we made in the sanitary district. This is a little out of our field, but in addition to our sewage work we collected some fifty or sixty samples a day from the suburban cities in the neighborhood of Chicago from Waukegan to Gary. We are making a study of bacterial efficiency of these plants, of the tastes and odors received in the Calumet District. The Calumet District has a number of by-product coke plants and industrial wastes of other character. We felt we might make a little study of what could be done with those wastes, stimulated to some extent by Mr. Enslow's visit.

On the Calumet waters we found it was necessary to use a considerable excess of chlorine, that is, certainly more than 1.00 p.p.m. for super-chlorination and then we require quite a period of contact. I think Mr. Harrison has referred to that. He said a minimum of two hours and Mr. Howard stated one and a quarter. That is a part of the process that requires time, and I think it will vary with various waters. We found it might take four or more hours, with the tastes in the waters with which we were working.

The next step in the dechlorination with sulphur dioxide is an immediate reaction and proceeds very nicely. We have used sodium dioxide or sodium sulphite can be used. We found that frequently there is a musty taste remaining after dechlorination. I believe Houston reports on one of the upland waters that a musty taste remains.

There is another point in regard to sulphur dioxide. A certain amount will be oxidized by the dissolved oxygen in the water, and

[9] Chief Chemist, Sanitary District of Chicago, Chicago, Ill.

the per cent of efficiency will vary somewhat, although I think Mr. Howard has worked out the per cent that he used in this reaction.

Those elements should be considered and each water should be studied on its own basis. We have another interesting experience with regard to pre-chlorination. There are two filter plants treating approximately the same type of water, highly polluted, with the B. coli index up to 50,000. East Chicago has been pre-chlorinating for some time. Whiting has not been pre-chlorinating and we find that East Chicago, using rather large amounts of chlorine, has been able to produce an effluent which meets the present standards for the past year without any exceptions, while Whiting, using we will say 5 or 6 pounds of chlorine, has not been able to meet that standard continuously. The difference is this. East Chicago applies the chlorine at the entrance to the coagulation basins and applies very large amounts. We have a record of one day when they applied 25 pounds per million. About 80 per cent of the chlorine is applied before the sedimentation acts and the remaining 20 per cent to the filtered water.

They are able to get the results by using these large amounts of chlorine. If it is a question of either producing tastes and odors or producing a safe water, I think they will have to use those amounts. It indicates to us, however, that where these highly polluted waters must be treated by pre-chlorination so as to produce a water meeting the new standard, considerably larger amounts of chlorine can be used. Whether that is economical is a debatable question, but it has been shown very conclusively that, by using these larger amounts, waters of the same character will show different results with the bacterial efficiency decidedly in favor of the plant using pre-chlorination.

Sheppard T. Powell.[10] It may be of interest to the men here to know what was done at the Avalon Plant of the Baltimore County Water Company in 1910. We started the use of chlorine at that time employing bleaching powder, the only chemical available. We had no idea how much to apply and we were using between 1 and 2 parts per million. The treatment was started in 1910, after the plant had been operating two years. The chlorine was applied at the entrance of the coagulating basin. The average result after five years

[10] Consulting Chemist, Baltimore, Md.

of treatment, compared with the two years before using the treatment, showed an increase in the lengths of runs of the filters of about 25 per cent. The wash water was reduced about $\frac{1}{2}$ of 1 per cent.

We later tried double treatment applying three-quarters of the dose before application to the filters, and about one-quarter after the filters. No tastes or odors resulted from the treatment. Our experience showed that the pre-chlorination removed the growths on sand beds and materially improved operating conditions.

ABSTRACTS OF WATER WORKS LITERATURE

FRANK HANNAN

Key: American Journal of Public Health, **12**: 1, 16, January, 1922. The figure 12 refers to the volume, 1 to the number of issue, and 16 to the page of the Journal.

Proceedings of Ninth Texas Water Works Short School. Texas Section, Southwest Water Works Association. January 24–29, 1927. These proceedings are divided into sections as follows: Section I. General; Section II. Water; III. Laboratory Methods and Control Studies; IV. Sewage Disposal; V. Appendix. **Section II: Raising the Standard of Public Water Supplies in Texas.** J. B. BAITY, 46. State Board of Health requires that plans and specifications for water works improvements be submitted for approval. The "Monthly Water Works Operation Report" form furnished by the State Board of Health and submitted by a number of cities in the state is designed to set forth a complete record for each day of the operation of the plant. Plants without laboratories are urged to submit samples regularly to the State Board of Health laboratory. **The New Three and a Half Million Dollar Water Supply, Waco, Texas.** O. N. FLOYD, 51. Water will be obtained from Bosque River by the construction of an earth dam of about 7000 feet total length. Basin formed will cover about 4500 acres and will store twenty-five billion gallons of water. Three and a half miles of 36 inch pipe will convey water to existing five million gallon filter plant. **Comparative Water Service in Texas Towns.** B. F. CHERRY, 57. Writer offers a basis upon which a water rate should be built in a town or city, municipally or privately owned. **A Texas Water Supply Enlargement Problem Involving a Dual Distribution System.** N. T. VEATCH, JR., 59. In arid and semi-arid parts of the country the large amounts of water used for irrigation places a heavy load on an otherwise adequate water supply, raising the question of economy in a separate system for irrigation. Wichita Falls is cited as an example where excessive use of water for irrigation has resulted in several near water shortages. Additional supply available is a hard and saline water suitable for irrigation, but not domestic use. Figures are given showing comparative costs of single and dual systems. Dual system is more expensive in first cost and in operation than single system, but should be considered where sufficient water is not available or supply requires excessive chemical treatment. **The San Antonio Flood Control Program.** S. F. CRECELIUS, 63. **Garza Dam and Reservoir Project Now Under Construction by the City of Dallas, Texas.** J. C. NAGLE, 72. Tabulation of dimensions, quantities, costs, items, etc. **Status of State Water Conservation Program for Levee Districts.** B. F. WILLIAMS, 75. **Financing City Water and Sewer Improvements.** TERRELL BARTLETT, 78. **Public Policy and Water Works**

Management. J. Z. Martin, 82. Greater politeness, more patience and courtesy and more sincere effort to obtain and keep the goodwill of the public is stressed. A water company should not only keep abreast of the times in its equipment for filtration and transportation, but also with changes involving office management. One hundred per cent metering and monthly billing are advised. **Responsibility of Water Works Officials in the Distribution of Water.** F. J. Von Zuben, 85. "An official who, taking office, neglects to investigate the condition of the public water supply and do everything in his power to make it adequate, betrays a sworn public trust and is a liability to his community rather than an asset." **Liability of a Municipality for the Quality of Water.** H. J. Darcy, 87. List of cases is given, in which decisions were rendered in favor of plaintiff on the basis of negligent operation or maintenance. **Cost, Accounting, and Records in Running a Water Works.** W. H. Deaton, 89. **Electrification of Water Plants.** F. C. Bolton, 92. Characteristics of reciprocating, rotary and centrifugal pumps is given, together with description of squirrel-cage induction, wound-rotor induction, synchronous and brush-shifting commutator motors. Advantages of pumps and motors and features to be considered in their selection is discussed. **Appraising Water and Sewer Systems.** R. E. McDonnell, 103. **Trained Personnel Versus "Hired Hand" Method of Filter Plant Operation.** G. F. Catlett, 109. An important cause of poor condition of filter plants is neglect or incompetent supervision. In North Carolina a systematic training and development is given by the State Board of Health. In addition to improvement in plant efficiency and greater assurance of safety, considerable economics have been effected, proving that the trained operator really does not cost any more than the man hired at random, without any regard for the qualifications required in handling water purification. **Combination Water Works and Sewage Disposal Plant Operators.** E. W. Steel, 113. **Supervising Water Improvements in California.** C. G. Gillespie, 115. **Dual Water Supplies.** A. L. Dopmeyer, 120. **Developing and Protecting Underground Water Supplies.** J. G. Montgomery, 125. **Economy of Softening Well Water Supplies.** Paul C. Laux, 129. In order to give comparative figures the author uses hypothetical community of 25,000 inhabitants, using water of 400 p.p.m. hardness. Figures indicate softening by municipal lime-soda softening plant, to cost approximately two-thirds that of softening by individual household softening plants. Discussion by Sidney B. Armsby gives figures for M. K. & T. Railroad softening plant at New Braunfels, Texas, as compared with same water delivered to town without softening. **Zeolitic Water Softening.** Ray Riley, 139. **Water Softening as an Adjunct to Water Purification.** Charles P. Hoover, 143. Softening process increases efficiency of filtration plant operation because better coagulation is effected, more organic matter and color are removed, the treated water is non-corrosive and intestinal and pathogenic bacteria are killed. The killing of bacteria makes it unnecessary to depend on chlorine where tastes and odors are feared. **Powdered Fuel and Boiler Room Economy.** L. V. Reese, 150. **Water Pumps and Power Machinery.** D. H. Hunter, 155. **Mechanical Equipment in Water Works Plants.** W. T. Alliger, 159. Specifications for the purchase of centrifugal pumps, electric motors, steam turbines, reduction gears and condensers. **Power Units and Mechanical**

Equipment. E. J. Fermier, 165. **Specifications and Analysis of Gravel and Filter Sand—Where Sand May Be Obtained.** Lewis O. Bernhagen, 169. **Modern Practice in Designing Aeration Units for Water and Sewage.** H. L. Thackwell, 173. **Value of Preliminary Sedimentation in Water Purification.** Frank Bachmann, 173. Advantages of preliminary sedimentation in treatment of turbid waters are: removal of bulk of turbidity, reducing load on coagulation basins and consequent cost of clearing these basins; gives a water low in turbidity resulting in smoother plant operation; reduces cost of chemicals for coagulation and softening; reduces cost of water wasted with sludge as this water has not been treated with chemicals. Graphs show saving in chemicals which may be obtained by pre-sedimentation. **The Development of the Hyraulic Jump Mixing Flume for Water Purification.** J. W. Ellms, 180. **Recent Developments in Water Purification.** George W. Fuller, 182. Superchlorination, dechlorination, split chlorination, prechlorination, double cogulation, double filtration, water softening, aeration, mechanically-cleaned settling basins, new coagulation method, boiler feed water, new purification works and experimental studies at Cincinnati on filter loading are all briefly discussed. **The Trend of Modern Methods in Water Purification.** C. Arthur Brown, 186. Trend appears to be toward more ornate and pleasing type of architecture for plant, improved surroundings, more and better equipment, more stringent standards of purity for water. Changes in processes have developed from plant where only turbidity and bacteria were removed to modern plant removing in addition to color, iron and hardness and possibly adding iodine for goitre prevention, and adding or removing carbonic acid when necessary. Sedimentation, chemical treatment, measurement and control of flows, filtration, softening recarbonating,. decarbonating, double treatment and sterilization development are outlined. **Relative Economy in Metering Services in Small Towns.** Chas. Ade, 200. **The Design of Filter Plants with Low Costs of Construction and Operation.** Jas. H. Fuertes, 205. **Description of plants constructed at Harrisburg and Steelton, Pa., Dallas, Tex., and Denver, Colorado.** Discussion by Frederick W. Weed, 211. **Measurement of the Quality of Water.** Jack J. Hinman, Jr., 213. The safety of a water is today considered first, its attractiveness second and its mineral content third when quality of a particular supply is investigated. Changing ideas as to quality, from ancient times to present day are reviewed. **Saving and Keeping Elevated Water Storage Tanks or Towers and Standpipes in Sanitary Condition.** D. W. Pyle, 219.—*A. W. Blohm.*

Proceedings Lake Michigan Sanitation Congress, Third Annual Meeting Racine, Wis. September 24–25, 1926. The Congress included representatives of 51 municipalities from the states of Wisconsin, Illinois, Indiana and Michigan, besides seven boards of commissions and several industrial commissions. **Annual Report of President.** Henry W. Lee, 5. **"The Case for Racine."** W. W. Bauer, M.D., 12. Review of typhoid fever, diarrhea, enteritis and quality of water supply of Racine. Filtration plant nearly completed consists of 2,600,000 gallon sedimentation basin, six 1,500,000 gallon filter units with plans for two more and a clear well with 3,000,000 gallons storage capacity. **The Izaak Walton League of America.** Charles W. Folds, 17. **Chicago**

Regional Planning Association. W. W. DeBerard, 18. **Stream Pollution in Michigan.** Edward D. Rich, 20. **A Visit to The Milwaukee Sewage Disposal Plant by the Lake Michigan Sanitation Congress.** T. Chalkley Hatton, 23. **Summary of Report on an Investigation of the Pollution of Lake Michigan in the Vicinity of South Chicago and the Calumet and Indiana Harbors—1924—U. S. Public Health Service.** Langdon Pearse, 31. Study undertaken comprised: sanitary survey of drainage area of Calumet River, utilizing available data from and supplementing same by additional field surveys; bacteriological studies of waters of Lake Michigan and public water supplies taken therefrom; collection and analysis of available data relative to influence of existing pollution of these water supplies upon public health; detailed study of precipitation and wind movement; as well as lake elevations in Calumet region. Survey of 123 industrial plants showed 14 plants to be discharging waste of sanitary significance. Survey of sanitary sewage indicates that along the water frontage of Hammond, Whiting, East Chicago and Chicago some 21,000 people discharge sewage directly into the lake. In Calumet River in Illinois some 30,000 people discharge. In Little Calumet River in Illinois and Indiana some 46,400 discharge. In Indiana Harbor Ship Canal, 1,500 discharge. Direction of flow in Grand Calumet River and Indiana Harbor Ship Canal is such that sewage from 93,900 persons flows at all times into the lake at Indiana Harbor. On watershed of Calumet River are 146,000 people whose sewage may possibly reach the lake if the Calumet River is completely reversed. Obvious remedy for present intolerable situation is abatement of existing pollution of lake.—*A. W. Blohm.*

Automatic Combustion Control. Leeds and Northrup Company, Bulletin 660, 1927. An automatic system of metered combustion control for boiler furnaces is described. An electrical current controlled by steam pressure and flow in the steam main cooperates with air or gas flow meters, furnace pressure meters, and stoker or fuel feeder meters to regulate stokers, fuel feeders, fans and dampers as required to preserve constant steam pressure, to secure the desired division of load among boilers, to insure the most favorable furnace percentage of excess air or CO_2, and to hold the most favorable furnace pressure. Each fire receives only its alloted air supply, regardless of whether it is thick or thin or whether one or several fires are fed from a common duct, or whether the furnace is near to or far from the chimney. The quantity of air supplied to burn each pound of fuel is definite. System permits manual intervention to any desired degree. Some of the boilers of a plant can, at will, be operated under hand control, with fuel and air automatically held in a fixed ratio, while the remaining boilers under full automatic control take care of the fluctuations in steam demand; or individual boilers can be operated by push button control or by actual manual adjustment of dampers, etc., as when bringing a cold boiler up to load. Apparatus and hook-ups are shown for both stoker and powdered fuel plants, also steam flow and pressure charts and CO_2 records illustrating the results attained in commercial plants under automatic control.—*A. W. Blohm.*

Celloboise as an Aid in the Differentiation of Members of the Colon-Aërogenes Group of Bacteria. H. N. Jones and L. E. Wise. J. Bact., **11**: 359–66, 1926. In a medium containing 0.5 per cent celloboise, 0.3 per cent beef extract, and 1 per cent peptone B. aërogenes produces acid and gas while B. coli does not.—*Edward S. Hopkins (from Chemical Abst.).*

Further Observations on the Utilization of the Salts of Organic Acids by the Colon-Aërogenes Group. S. A. Koser. J. Bact., **11**: 409–16, 1926. The utilization of several organic acids of the dicarboxylic and tricarboxylic series by B. coli., B. aërogenes and related types were studied. Although the acids were structurally similar to citric, none afforded the same distinction between intestinal B. coli and other members of this group. B. coli was unable to use any of these acids with the possible exception of glutaric.—*Edward S. Hopkins (from Chem. Abst.).*

The Concentration of Sea Water as Affecting its Bacterial Population. C. B. Lipman. J. Bact., **12**: 311–3, 1926. One to one dilutions of sea water seems to result in a depressing effect on the growth of B. calcis on plates. Further dilution is completely destructive to the organism.—*Edward S. Hopkins (from Chem. Abst.).*

Note on the Occurrence of Bacteria in Oil Well Brine Samples. S. L. Neave and A. M. Buswell. J. Bact., **12**: 133–4, 1926. Thirty per cent of ninety-four samples showed denitrification. Further work may show that bacteria play a part in the chemistry of oil deposits.—*Edward S. Hopkins (from Chem. Abst.).*

The Destruction of Acetylmethylcarbinol by Members of the Colon-Aërogenes Group. F. S. Paine. J. Bact., **13**: 269–74, 1927. It seems probable that the transient Voges-Proskauer reaction is due in most cases to destruction of the acetylmethylcarbinol by the organism. Some strains of B. coli and B. aërogenes can do this. A false negative in an old culture of B. aërogenes is probably not due to the exhaustion of peptone.—*Edward S. Hopkins (from Chem. Abst.).*

Viability of Bacterium Typhosum in Ice Cream. M. J. Prucha and J. M. Brannon. J. Bact., **11**: 27–9, January 1926. Although this work considers the presence of B. typhosum in ice cream, yet it is of interest since it shows that the initial count of 51,000,000 colonies per cubic centimeter had decreased in five days to 10,000,000, in twenty days to 2,000,000, in a year to only 51,000; but even after two and one half years living organisms were still present. The material was kept at an average temperature of $-4°$F. during the experiment.—*Edward S. Hopkins.*

A Method of Staining Bacterial Flagella. P. H. H. Gray. J. Bact., **12**: 273–4, October, 1926. A modification of Muir's method is given which is shown to be quite successful.—*Edward S. Hopkins.*

A Light Switch for the Microscope. C. S. Mudge. J. Bact., **13:** 223–4, March 1927. Description of a handy switch to provide dual illumination for a microscope is given.—*Edward S. Hopkins.*

Gentian Violet Lactose Peptone Bile for the Detection of B. coli in Milk. Mildred A. Kessler and Joseph C. Swenarton. J. Bact., **14:** 47–53, July 1927. A new medium is suggested for the detection of B. coli in milk. It is a modification of the brilliant green bile medium suggested by Muir and Harris, using gentian violet in the place of the former dye and a weaker strength of bile (1 per cent). One thousand and ten (1010) examinations for B. coli were made and all except ten showed growth typical for members of the group. [This methods is applicable to isolation of B. coli from water and is believed to be superior to plain lactose as evidenced by collaborative work in the abstractor's laboratory]—*Edward S. Hopkins.*

The Rate of Solution and Availability of Commercial Limes. R. T. Haslam, F. W. Adams and R. H. Kean. Ind. Eng. Chem., **18:** 19–23, 1926. The rate of solution (which in general determines the availability of lime) is shown to depend on the fineness and is directly proportional to the area and solubility of the lime. In acid forming a soluble lime salt, the increase in rate of solubility over that in water is proportional to the concentration of the acid. If an insoluble salt is formed, the rate of solution is decreased. For an availability test to be of value, it should be based upon the particular process in which the lime is to be used. Graphs are given.—*Edward S. Hopkins (from Chem. Abst.).*

Corrosion of Steels in the Atmosphere. W. G. Whitman and E. L. Chappell. Ind. Eng. Chem., **18:** 533–5, 1926. The relative rates of corrosion of steel samples in the American Society for Testing Materials' long time atmosphere exposure test and in a rapid water spray tester are shown to be the same. The rate of atmospheric corrosion is related to the time the metal is wet and to the impurities in the atmosphere.—*Edward S. Hopkins (from Chem. Abst.).*

Effect of Oxygen Concentration on the Corrosion of Copper by Non-Oxidizing Acids. R. P. Russell and A. White. Ind. Eng. Chem., **19:** 116–8, 1927. Experiments were made to study the effect of dissolved oxygen on the corrosion of copper in dilute sulfuric, acetic, and hydrochloric acids. The corrosion was directly proportional to the concentration of dissolved oxygen. Graphs, tables, and photomicrographs are given.—*Edward S. Hopkins (from Chem. Abst.).*

Volumetric Determination of Alumina in Aluminium Salts. F. G. Germuth. Ind. Eng. Chem., **19:** 144–5, 1927. The method depends upon precipitating aluminium hydroxide with ammonia using methyl red as indicator, heating to boiling, filtering, dissolving the precipitate in a known volume of standard acid, and titrating the excess with standard alkali using methyl orange as indicator.—*Edward S. Hopkins (from Chem. Abst.).*

Controllable Variables in the Quantitative Study of the Submerged Corrosion of Metals. O. B. J. Fraser, D. E. Ackerman and J. W. Sands. Ind. Eng. Chem., **19**: 332–8, 1927. The effects of oxygen, concentration, temperature, velocity, and concentration of active ions in submerged corrosion in acid are studied. Data are given for the corrosion of Monel metal and testing apparatus is discussed.—*Edward S. Hopkins (from Chem. Abst.).*

Recent Developments in Zeolite Softening. A. S. Behrman. Ind. Eng. Chem., **19**: 445–7, 1927. An outline is given of zeolite softening up to the present time. The present synthetic "gel" zeolites are made by mixing sodium silicate and aluminum sulfate, or sodium aluminate and sodium silicate, of the proper concentration, drying and crushing. By means of this zeolite a much higher rate of exchange is obtained and economy is effected in operation and maintenance.—*Edward S. Hopkins (from Chem. Abst.).*

The Influence of Rust Film Thickness on the Rate of Corrosion of Steels. E. L. Chappell. Ind. Eng. Chem., **19**: 464–7, 1927. The chemical characteristics of the surfaces of different steels determine their corrosive rates in the absence of rust films. In submerged corrosion, decreases in corrosion rates are shown to be proportional to the thickness of the rust film formed.—*Edward S. Hopkins (from Chem. Abst.).*

Some Variables Affecting the Behaviour of Limes Used in Causticizing. J. V. N. Dorr and A. W. Bull. Ind. Eng. Chem., **19**: 558–61, 1927. The nature of the final precipitate can be greatly modified and its settling rate changed at least fifty fold, by changing the method of slaking and causticizing. Relative particle size may persist through the course of a chemical reaction between a solid and a solution.—*Edward S. Hopkins (from Chem. Abst.).*

The Intercrystalline Corrosion of Metals. H. S. Rawdon. Ind. Eng. Chem., **19**: 613–9, 1927. Numerous examples of the intercrystalline corrosion of several metals are cited. The effect of stress, both internal and external, and impurities in the metal are given. The importance of this type of corrosion in the cracking of metals is stressed. Preventive measures include annealing, protective coatings, and elimination of corrosive conditions.—*Edward S. Hopkins (from Chem. Abst.).*

The Embrittlement of Boiler Plate. S. W. Parr and F. G. Straub. Ind. Eng. Chem., **19**: 620–2, 1927.; cf. C. A. **20**: 2814. Embrittlement of boiler plate is caused by the action of sodium hydroxide on the metal under stress. A concentration of 6000 grains per gallon is necessary to produce cracking. Sodium sulfate will prevent embrittlement. Recommended ratios of sulfate to hydroxide are given.—*Edward S. Hopkins (from Chem. Abst.).*

The Mineral Waters of Courmajeur. Giovanni Issoglio. Ann. accad. agr. Torino, **67**: 3–17, 1924. From Chem. Absts., **20**: 2132, July 10, 1926. Physical constants of radioactivity and chemical composition of waters of "La Saxe" (sulfuretted), "Vittoria" (carminative), and "Regina" (chalybeate) springs are given.—*R. E. Thompson.*

Report on Waters, Brine and Salt. **(Determination of Hydrogen Sulfide in Water.)** C. H. Badger. J. Assoc. Official Agr. Chem., **9**: 125–7, 1926. From Chem. Abst., **20**: 2216, July 10, 1926. Collaborative comparison of old official method and method proposed by B. (C. A. **19**: 2383) showed latter to possess following advantages: greater rapidity, easier calculations, more concordant results, greater accuracy because larger samples can be taken, especially with relatively high hydrogen sulfide contents. Neutralization of acid samples is unnecessary. Alkaline samples must be neutralized, otherwise abnormally high results are obtained.—*R. E. Thompson.*

The Determination of Ammonia in Ammoniacal and Industrial Waters. Charles Jungblut. Bull. soc. chim., **39**: 336–7, 1926. From Chem. Absts., **20**: 2216, July 10, 1926. Twenty cubic centimeters of the water is placed in 100-cc. flask, 10 cc. 5 per cent sodium hydroxide and 15 cubic centimeters 20 per cent barium chloride added, and mixture diluted to 100 cc. and filtered. Twenty cubic centimeters of filtrate, corresponding to 4 cc. of original water, is neutralized with hydrochloric acid with methyl orange as indicator and 5 cc. of 40 per cent formaldehyde added. The ammonia is transformed into hexamethylenetetramine and corresponding free acid is titrated with 0.1 N. sodium hydroxide with phenolphthalein as indicator. Method checks to within about 2 per cent with distillation method.—*R. E. Thompson.*

Filter for Water. D. Hall, J. H. Kay and Hall, & Kay, Ltd. Brit. 240, 211, June 19, 1924. From Chem. Absts., **20**: 2218. July 10, 1926.—*R. E. Thompson.*

The Control of Alum Dosage in Water Purification. F. Egger. Chem.-Ztg., **50**: 167, 1926. From Chem. Abst., **20**: 2216. July 10, 1926. Determination of decrease in carbonate hardness, pH, and reduction in turbidity are the best methods of controlling addition of alum to water.—*R. E. Thompson.*

Annual Reports of the Division of Water, Division of Sewage Disposal and Bureau of Water Works Extension, 1925. C. B. Hoover, C. P. Hoover and C. D. McGuire. Supplement to The City Bull. (Columbus, Ohio), 16–47. From Chem. Abst., **20**: 2216, July 10, 1926. Hardness is reduced to 92 p.p.m. by split treatment, a reduction greater than could be effected with same quantities of lime and soda ash by ordinary method. Expense prohibits hot process, and disagreeable tastes prohibit over-treatment method.—*R. E. Thompson.*

The Chlorine Sterilization of Drinking Water. R. Schwarzbach. Gas u. Wasserfach **69**: 272–5, 1926. From Chem. Abst., **20**: 2217, July 10, 1926. Much greater efficiency of chlorine as compared to calcium hypochlorite, especially during high water seasons, shown by numerous tabulated tests.—*R. E. Thompson.*

Engineering Aspects of Treating Textile Water Supplies. H. L. Tiger. Mech. Eng., **48**: 435, 1926. From Chem. Abst., **20**: 2217, July 10, 1926. Gen-

eral description given of chemical feed apparatus, settling tanks, filters, and water softeners for treatment of water for textile industry. Removal of hardness by zeolite softeners is recommended as sodium salts do not react with soap or dyestuffs. Excess soda ash and lime, necessary for complete removal of hardness by lime-soda process, is highly undesirable in this industry. Care must be taken to prevent contamination by algae, iron, or organic matter after treatment.—*R. E. Thompson.*

Apparatus for Softening Water with Zeolites, etc. K. A. Spearing and J. Kerr-Bock. Brit. 240, 598, August 9, 1924. From Chem. Abst., **20**: 2218, July 10, 1926.—*R. E. Thompson.*

The Determination of Dissolved Oxygen in Effluents. E. R. Trotman. Chem. Ind., **45**: 110T, 1926. From Chem. Abst., **20**: 2217, July 10, 1926. To rubber-stoppered bottle of about 260 cc. capacity, fitted with funnel and side tube with stopcocks, add 10 cc. petroleum and water to fill up almost to mark. Add water to complete required volume, and add reagents through funnel, which should extend to bottom of bottle.—*R. E. Thompson.*

Transportation of Liquefied Chlorine Gas. H. P. Wells, H. M. Mabey and J. M. Rowland. Trans. Am. Electrochem. Soc., **49**: (preprint) 1926. From Chem. Abst., **20**: 2230, July 10, 1926. Regulations of Interstate Commerce Commission re-shipping of liquid chlorine reviewed. Specifications cited for testing the steel containers, construction of valves, filling and emptying cylinders, and precautions in transportation. New tank cars, and methods of filling and emptying, are also described.—*R. E. Thompson.*

Fused Cement and Sands Containing Humic Acids. A. F. Roscher. Teknisk Ukeblad; Rev. mat. constr. trav. pub., **197**: 33–5, 1926. From Chem. Abst., **20**: 2236, July 10, 1926. Compression tests were made to determine relative strengths of portland and fused cements when mixed with sands containing humic acids. Content of humic acid was determined colorimetrically by comparison of an ammoniacal extract of the samd with a standard solution. Results indicated that presence of humic acid reduces strength of portland cement to much greater extent than that of fused cement. With former, effect is due to chemical reactions, while with latter effect is due to physical and mechanical factors.—*R. E. Thompson.*

The Radium Content of the Hot Springs of Gastein and Karlsbad. Heinrich Mache and Felix Kraus. Physik. Z., **27**: 205–6, 1926. From Chem. Abst., **20**: 2278, July 20, 1926. Radium content of springs at Gastein varies from 0.2 to 154, expressed in billionths of grams per litter, and of those of Karlsbad from 34.7 to 53.9.—*R. E. Thompson.*

Action of Natural Alkali Waters on Portland Cement. G. W. Burke. Proc. Iowa Acad. Sci., **31**: 277, 1924. From Chem. Abst., **20**: 2236. July 10, 1926. Magnesium salts are most active on cement. Magnesium sulfate in intimate contact with cement reacts very rapidly with all calcium in latter, producing

calcium sulfate and an insoluble compound of magnesium. The reaction results in material increase in weight and volume of cement. Magnesium chloride rapidly reacts with cement, replacing practically all the calcium by magnesium. Chemically equivalent amounts of calcium and magnesium are involved in the exchange. Slight decreases in weight and volume of cement accompany this reaction. Salts of sodium are less active than corresponding salts of magnesium.—*R. E. Thompson.*

Some Properties of Lumnite Cement. L. J. Rothgery. Mich. Eng. Expt. Sta., Bull. **4**: 1926. From Chem. Abst., **20**: 2236, July 10, 1926. Lumnite cement concrete subjected to freezing immediately after mixing failed to stand a satisfactory test. Same concrete when allowed time for hydration after thawing attained strength slightly below that of samples cured under normal conditions. Concrete subjected to freezing after final set had occurred attained usual 24-hour strength. In general, ultimate strength of Lumnite cement concrete is not affected by freezing. Suggestions are made for protection of concrete during freezing weather. Study was also made of bond between portland cement and Lumnite cement under varying conditions.—*R. E. Thompson.*

California Quick Hardening Concrete. C. L. McKesson. California Highways, **2**: 11, 6–8, 1925; Rock Products, **29**: 5, 46–7, 1926. From Chem. Abst., **20**: 2237, July 10, 1926. Tests of high early strength concrete using 6 sacks portland cement, 7 sacks portland cement plus 2 per cent calcium chloride, and 6 sacks Lumnite cement per cubic yard of concrete gave compressive strengths at 24 hours of 951, 2020, 5360; at 48 hours, 1722, 2860, 5862; and at 28 days, 4338, 4751, 5796 pounds per square inch. Costs of cement (and calcium chloride) per square yard of 6-inch pavement were $0.70, 0.86 and 2.12.—*R. E. Thompson.*

Substances in Rain and Snow. Nicholas Knight. Proc. Iowa Acad. Sci., **31**: 325–6, 1924; cf. C. A., **16**: 3993; **17**: 1854; **18**: 2776. From Chem. Abst., **20**: 2379, July 20, 1926. Twelve samples of snow and 29 of rain were collected and analyzed during period October 1, 1922—June 1, 1923. Chlorides varied from 3.54 to 28.1 p.p.m. Total nitrogen averaged 0.896 p.p.m., and was constant; free ammonia 0.34; albuminoid ammonia 0.264; nitrogen in nitrates 0.346 and in nitrites 0.397; sulfates (SO_3) 0.147.—*R. E. Thompson.*

Composition of Lake Epecuén Water and Its Applications. H. Corti. Añales asoc. quim. Argentina, **23**: 509–26, 1925. From Chem. Abst., **20**: 2379, July 20, 1926. Tables of analyses.—*R. E. Thompson.*

The Preparation of Zeolitic Water-Softening Materials. E. L. Barthel. Proc. Iowa Acad. Sci., **31**: 275–6, 1924. From Chem. Abst., **20**: 2380, July 20, 1926. Raw untreated greensand is very colloidal and has little or no water-softening power. By heating it to 400° and subsequently treating it with sodium chloride solution, stable zeolitic sand is obtained which has good water-softening power. This method is in use at present time. Modification of this

treatment gives zeolite with greater water-softening power. Sand is first treated with concentrated calcium chloride solution and subsequently with concentrated sodium chloride solution, then rapidly heated to about 800° and quenched in salt solution.—*R. E. Thompson.*

Water-Softening Reagents. A. S. Behrman and W. H. Green. Can. 258,822, March 9, 1926. From Chem. Abst., **20**: 2381, July 20, 1926. Base-exchange material is prepared by treating natural greensand with solution of caustic alkali and drying product to remove excess moisture.—*R. E. Thompson.*

Apparatus for Softening Water, etc. I. B. Tanner. U. S. 1,587,129, June 1. From Chem. Abst., **20**: 2381, July 20, 1926.—*R. E. Thompson.*

Water-Softening Reagent. A. S. Behrman. Can. 258,823, March 9, 1926. From Chem. Abst., **20**: 2381, July 20, 1926. Base-exchange material is prepared by soaking greensand in alkali salt solution and then in alkali silicate solution.—*R. E. Thompson.*

Base-Exchange Silicate. H. J. Wheaton. U. S. 1,586,764, June 1. From Chem. Abst., **20**: 2381, July 20, 1926. Double base-exchange silicate is prepared in which practically all soluble substances formed by reaction of constituent solutions are retained in the gel.—*R. E. Thompson.*

Detection and Determination of Free Chlorine in Drinking Water. I. M. Kolthoff. Chem. Weekblad, **23**: 203–4, 1926. From Chem. Abst., **20**: 2380, July 20, 1926. Add to 100 cc. water few drops of acetic acid, 1–2 cc. 2 N sodium acetate, and 10 drops 0.1 per cent dimethyl-*p*-phenylenediamine. Compare with iodine solution of known strength. Sensitiveness is 0.03 p.p.m. Reagent gives red color with all weak oxidizing agents, and is decolorized by excess. Ten parts per million iron can be detected in acetic acid-sodium acetate solution, while addition of sodium bicarbonate reduces sensitiveness considerably. Tetramethyl-*p*-phenylenediamine gives violet color.—*R. E. Thompson.*

Recommended Process for Bronze-Welding Cast Iron Pipe Not Exceeding 12-Inch Diameter. Linde Air Products Co. Proc. Am. Gas Assoc., 1925, 981–8. From Chem. Abst., **20**: 2306, July 20, 1926. Details given covering all phases of work, including training and examination of welders, organization of crews for laying welded pipe, specifications for pipe, welding rod and flux, and method of welding proper.—*R. E. Thompson.*

Geology and Water Supply in the Vicinity of Danzig. H. Stremme. Gas- u. Wasserfach, **69**: 437–42, 1926. From Chem. Abst., **20**: 2474, August 10, 1926.—*R. E. Thompson.*

Hydrogen-Ion Concentrations of Waters of Norwegian Mountains, and Their Bearings Upon the Classification of Freshwater Localities. K. Münster Strom. Nyt Mag. Naturvidensk. (Oslo), **62**: 237–44, 1925; Botan. Abst.,

14: 1286. From Chem. Abst., **20**: 2349, July 20, 1926. H-ion concentrations of 71 bodies of water were determined. Aëration and stagnation play most important part in determining the pH. Mean value was 7.6 in 10 typically aërated bodies and 4.5 in 35 typically stagnant bodies. In peaty bogs, carbon dioxide assimilation by algae never sufficed to raise pH to appreciable extent, but when such water was aerated in brooklets, etc., reaction soon approached normal. Specific reaction of water is potential factor in determining character of biota in general, and especially the algal flora; but it must be considered in conjunction with other physical and chemical properties of the water.—*R. E. Thompson.*

The Elimination of Phenol-Bearing Wastes in the Gas Industry. R. L. Brown. Am. Gas. Assoc. Monthly, **8**: 211–4, 240, 254, 279–82, 1926. From Chem. Abst., **20**: 2405, July 20, 1926. Coke quenching with phenol-containing ammonia still waste leads to corrosion difficulties due to vapors evolved. Waste can be handled in activated sludge plant provided its volume is not more than 5 to 10 per cent of total volume of sewage. Most practical methods appear to be "bacterial filter" consisting of lignite or similar material revivified by bacterial action, and benzene extraction system in which phenols are recovered from weak ammonia liquor before entering still. Experimental and plant data are given relating to latter processes.—*R. E. Thompson.*

The Washington Suburban Sanitary District. Robert B. Morse. Proc. Am. Soc. Munic. Improvements, pages 181–91, 1926–7. The Maryland suburbs of Washington comprise a number of small towns lying in two counties. The water systems in general were too small and delivered water inadequate in amount and poor in quality. The sewerage systems were also inadequate in many instances. The legislative act establishing the Washington Suburban Sanitary District was passed in 1918. The district has an area of 96 square miles and a population of about 50,000. A commission of 3 members administers the affairs of the district. The commission has the powers usually accorded to municipal officials with respect to construction and operation of water and sewerage systems. Its bond issues must be approved by the Public Service Commission, and its charges and rates are subject to review by that body. District bonds for construction work may be issued, without referendum, up to 12 per cent of the assessed value. All of the municipal and private water and sewerage systems have been acquired by purchase. The purchased systems comprised about 53 miles of water mains and 60 miles of sewers. The water system now contains about 200 miles of mains and the sewerage system about 150 miles of sewers. There are about 8,500 water connections and 7,200 sewer connections. Outstanding bonds amount to nearly $6,000,000. Three water filtration plants with a total capacity of 5 million gallons daily barely supply the requirements during periods of excessive demand. The fixed charges on bonds are met through a small addition to the tax rate over the whole district and a front-foot benefit charge on property abutting on water and sewer lines. The water rates cover the maintenance and operating expense on both water and sewerage systems. The charge on the tax rate represents theoretically the fixed charges on part of

the construction cost of purification and pumping works, trunk lines, etc. Most of the cost of construction is borne through front-foot benefit charges on property abutting on water mains and sewers. All construction work except the installation of house connections is accomplished by long-term sinking-fund bonds. The benefit charge is spread over the life of the bonds, payable in the form of a small annual sum. This feature has done more than any thing else to permit the construction of water and sewer systems in a sparsely settled suburban area. The property owner has the privilege of paying off the benefit charge at any time. The rates include a fixed ready to serve charge of from $4.00 for a $\frac{5}{8}$-inch meter to $360.00 for an 8-inch fire line meter, and a consumption charge varying from 18 cents per thousand gallons for the first 50,000 gallons used semi-annually to 9 cents per thousand gallons for all water consumed above 2,500,000 gallons monthly. Public fire hydrant service and water for municipal uses are furnished free. The coagulation of the water at the filtration plants is under pH control all the time and the filter effluents are constantly observed through turbidity detectors attached to the effluent piping.—*John R. Baylis.*

The Need of Metropolitan Utility Districts. V. B. Siems and D. B. Biser. Proc. Am. Soc. Munic. Improvements, pages 236–46, 1926–7. It may be assumed that isolated plants will give way to single giant developments more capable of providing the utility at a lower cost. Improvements in transportation makes the dispersal of the urban population into the country greater than heretofore. To construct and operate utilities to serve sparsely settled territory requires enormous capital investment. The lack of foresight in reserving water supply for the future is a danger to growth, for it is the predominant safeguard of health, protection against fire danger, business and industrial interruptions, and disruption of home comforts. Curtailment of water supply sources by the grant of water power rights sometimes requires the development of further removed sources. The Federal Water Power Act passed in 1920 failed to make provision for safeguarding the interest of the cities and towns which may be forced to go to navigable streams or their tributaries for water supplies. The authors urge that action be taken to save the rights of the public. The State of Nebraska has enacted laws governing metropolitan utility districts, which provide that whenever a metropolitan city and one or more adjacent municipalities or precincts are served in whole or in part by one water works owned and controlled by the metropolitan city, the territory included constitutes a metropolitan district. The authors recommend that adequate legislation be secured to establish utility districts. —*John R. Baylis.*

Microscopic Life in Texas Waters. John B. Hawley. Proc. Am. Soc. Munic. Improvements, pages 247–77, 1926–7. The author gives the history, morphology, and phagology of microscopical organisms occurring abundantly in many water supplies of Texas. There is a good explanation of the occurrence, viability, length of life, and seasonal distribution of such organisms. The tables by Kellerman showing the susceptibility of a number of microorganisms and fish to copper sulfate are given. Twenty-nine plates from

drawings and 9 from microphotographs illustrate a number of organisms commonly found in Texas waters.—*John R. Baylis.*

NEW BOOKS

Standards Yearbook—1927. National Bureau of Standards, Department of Commerce. The first issue of the Standards Yearbook "represents an effort to present an adequate picture of the diversification and ramification of the standardization movement which has spread throughout the world with astonishing vitality during the 25 years that have elapsed since the establishment of the National Bureau of Standards. It contains outlines of the activities and accomplishments of not only this bureau and other agencies of the Federal Government and the States and municipalities, but also of the American societies and associations of which standardization is a major or very important activity. Descriptions and illustrations are presented of all the fundamental national standards of the United States. Moreover, outlines are given of the various foreign, national, and the several international standardizing agencies."—*A. W. Blohm.*

JOURNAL

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NOTICE

Superintendents' Question Box

For many years in the past it has been the practice to report quite fully in the Journal and to discuss at considerable length at annual convention meetings, a series of topics of interest to superintendents. These topics have generally been listed under the "Superintendents' Question Box Series." In the preparation of programs for annual sessions, the Publication Committee is frequently at a loss to determine which of the questions ordinarily discussed are of greater interest than others to the superintendents.

It would be decidedly helpful, therefore, if all those persons interested in these particular topics would communicate promptly with the undersigned in order to assist him in the choice of question box topics which would supply most completely the requirements of the superintendents' group.

C. A. Emerson, Jr., Chairman,
Publication Committee.

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Discussion of all papers is invited

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THE WATER SUPPLY PROJECT OF THE MAHONING VALLEY SANITARY DISTRICT[1]

By W. H. Dittoe[2]

In many of the metropolitan areas of the United States and other countries the organization of districts has been adopted as an advantageous means of providing public improvements of wide variety, including water supply, sewerage, sewage disposal, drainage, flood protection, parks and other projects. Of the earlier districts organized in this country mention may be made of the Boston Metropolitan Water and Sewerage Districts and the Sanitary District of Chicago formed about 1890 to 1895. During the past twenty-five years the district plan of procedure has received impetus and many organizations have been effected for a variety of purposes. Some of those more recently formed are the Washington Suburban Sanitary District, The Miami Conservancy District (Ohio) for flood protection, The New Jersey Water Supply Districts, the various Illinois Sanitary Districts and the several municipal utility districts of California. The Winnipeg, Vancouver and Essex Border Districts in Canada should also be cited.

In Ohio legislative authority was given in 1919 for the formation of sanitary districts for purposes of water supply and sewage disposal,

[1] Presented before the Central States Section meeting, September 15, 1927.

[2] Chief Engineer, The Mahoning Valley Sanitary District, Youngstown, Ohio.

by enactment of the Sanitary District Act of Ohio, and The Mahoning Valley Sanitary District, organized February, 1926, is the first major undertaking pursuant to this law.

This district comprises the cities of Youngstown and Niles, having present estimated populations of 162,700 and 17,900 respectively and was formed for the purpose of providing a satisfactory public water supply for their joint use. The work of the District, preliminary to construction, has been in progress for the past 15 months during which extensive investigations have been conducted and a plan of water supply prepared, which has recently been submitted to the Board of Directors of the District. It is expected that construction will be undertaken in the spring of 1928.

The purpose of this paper is to explain briefly the conditions leading to the establishment of the District, the provisions of the Sanitary District Act controlling the procedures followed and the general features of the recommended plan.

CONDITIONS LEADING TO THE ESTABLISHMENT OF THE DISTRICT

"The Mahoning Valley" is a term commonly used to designate the intensively developed industrial district extending along the Mahoning River from the Pennsylvania State Line upstream to Newton Falls a distance of about 42 miles. Within this zone are nine municipalities, with a total population of 250,000, of which Youngstown, Niles and Warren are the most important.

The Mahoning Valley has attained its rank as one of the leading population centers of Ohio by reason of the growth which has attended the development of the iron and steel industry, its outstanding activity.

All of the sewage from the municipalities and other sewered areas of the valley reaches the Mahoning River without treatment and practically all industrial wastes are similarly disposed of. The river water is used extensively for cooling and condensing purposes, a total of approximately 800 million gallons daily being pumped and repumped from the stream representing $8\frac{1}{2}$ times the minimum flow available with present facilities for river regulation furnished by the Milton Reservoir. As a result the Mahoning River, draining an area of about 1000 square miles in Ohio, is grossly polluted, especially at points downstream from Warren, below which the valley is almost continuously occupied by industrial, residential and commercial development. In spite of its condition the river serves as a source

of public water supply for Warren, Niles and Youngstown, the three principal cities of the valley, each of which operates a filtration plant in the attempt to render the river water suitable for use. Above Warren the pollution of the river is less intense than below, and thus far the water supply of that city has not been affected to a degree necessitating remedy. At Niles and Youngstown, however, the condition of the river supply has become so bad that it is impossible to produce a satisfactory water notwithstanding unusually resourceful operation of the filtration plants, at both of which lime is used in amounts to produce causticity. The final product as delivered to consumers is of high degree of hardness, due principally to industrial wastes, of offensive taste and odor reflecting the gross pollution of the source, and of abnormal temperature during the warmer dry weather months of the year due to extensive use of their river water for cooling purposes. The water is not only unsuitable for drinking and other domestic uses, but causes rapid depreciation of plumbing, piping, heating systems and boilers by both incrustation and corrosion. Moreover, while the lime treatment has thus far been successful in coping with the excessive bacterial load and while typhoid fever has been of rare occurrence recently in Youngstown and Niles, no factor of safety exists and there is the ever present possibility of explosive outbreak of waterborne disease resulting from accidental interruption or failure of the treatement process.

An urgent popular demand for a satisfactory water supply has existed in both Youngstown and Niles for many years and both cities have made previous investigations of possible means of improvement of their respective supplies. It was not until the enactment of the Sanitary District Act in 1919 however that a definite impetus was given to the project of providing a remedy for the present unsatisfactory conditions. The passage of this law afforded for the first time the possibility of joint action of the two municipalities in the solution of their common water supply problem and after full consideration of the various questions involved conclusion was reached by the officials and representative citizens of each city that this common problem would best be solved through formation of a District. Initiative action was therefore taken by the city councils and citizens of Youngstown and Niles in the submission of a petition to the Court of Common Pleas of Mahoning County, upon the hearing of which the Court on February 2, 1926, ordered the formation of the District for the purpose of providing a satisfactory public water supply for the two municipalities.

PROVISIONS OF LAW

The Sanitary District Act of Ohio, which is of general application throughout the State, permits the organization of districts, including two or more political subdivisions or parts thereof for either or both of the following purposes: (a) improved water supply and (b) improved sewage disposal. As The Mahoning Valley Sanitary District was formed solely for the purpose of improved water supply only the provisions of the law applicable to this purpose will be discussed.

No municipality may be included in a District for water supply unless petition is made by the governing body or by the water company which may be supplying water under franchise. Such petition is heard by the Court of Common Pleas, a joint court being formed in case two or more counties are involved, and, upon finding being made organizing the District, it becomes a political subdivision of the State for the purpose of its establishment. The Court appoints a Board of Directors to manage the affairs of the District and a Board of Appraisers to appraise values of property to be acquired and damages and benefits which will result from the improvement. The Board of Directors is required to prepare a plan which is subject to hearing and review by the Court. The Board of Appraisers must submit a report of its findings to the Court, for approval, opportunity being given for full hearing of any objections thereto. It is required that the value of benefits resulting from the improvement, as reported by the Appraisers and approved by the Court, be at least equal to the estimated cost.

After court approval of the appraisal and plan the Board of Directors is authorized to levy assessments upon benefited units and to issue and sell District bonds in anticipation of collection of such assessments. Annual assessment levies are provided for to produce the amounts required each year for interest and amortization. The law requires that assessments must be levied upon the benefited units in proportion to the benefits appraised and not in excess thereof.

In the case of The Mahoning Valley Sanitary District it is proposed to assign all benefits to the two member cities as such and to avoid appraisal of benefits to individual properties within each city. The assessments will thus be made on each city as a unit and in accordance with the Sanitary District Act each city is empowered to collect a special tax levy to secure the amount necessary to meet each annual installment.

When funds are secured from the sale of bonds or from loans made in anticipation thereof, the Board of Directors is empowered to acquire land and to proceed with construction, either directly or by award of contracts in the usual manner. Ample power to carry out the purposes of the District is conferred upon the Board.

After the works have been constructed it is the duty of the Board of Directors to maintain and operate them. Funds for this purpose are to be secured by sale of water to the member municipalities at uniform rates to be adjusted from time to time to produce the necessary income.

THE PLAN FOR THE DISTRICT WATER SUPPLY

Preliminary to the preparation of the recommended plan a thorough canvass was made of all sources of supply within reasonable reach of the District and it was found that the best and most economical water supply would be secured by development of Meander Creek, a tributary of the Mahoning River, constructing a dam and forming a large storage reservoir for regulating of the supply. Following selection of this source a thorough study was made of the several means by which the chosen supply might be delivered to the District including (a) delivery of raw water to the existing plants and (b) provision of complete new District purification and pumping works so as to deliver purified water to the member cities. It was concluded that the individual interests of Youngstown and Niles and the purpose of formation of the District would best be served, with greatest ultimate economy, by the delivery of purified water from the Meander Creek supply.

In accordance with the major conclusions resulting from the preliminary investigations, the recommended plan of water supply for the District provides for the development of Meander Creek, the purification of this supply at the source and delivery of the purified supply by pumping to the present distributing systems of Youngstown and Niles.

The essential features of the plan include:

1. The Meander Creek Reservoir formed by the construction of the Mineral Ridge dam.
2. Purification and pumping works located immediately below the dam.
3. Pipe lines for delivery of the purified supply to the two cities.
4. A covered distributing reservoir in Youngstown and a steel standpipe in Niles, for reserve storage of water on the distributing systems.

The cost of execution of this plan is estimated at $9,150,000 made up of the following principal elements:

Dam and reservoir	$3,781,960
Purification and pumping works	2,310,030
Pipe lines and distributing reservoir for Youngstown	2,661,600
Pipe lines and standpipe for Niles	396,410

Meander Creek which enters the Mahoning River from the south at Niles drains an area of about 90 square miles which is mainly a rolling farm country containing a population of 55 persons per square mile and no serious sources of pollution by sewage or industrial wastes. This stream is at a much shorter distance from the center of consumption of the District than any of the other sources considered. The Mineral Ridge dam site in air line distance is about 7.8 miles westerly from the center of Youngstown and about 2 miles southerly from the center of Niles.

The dam will be of the earth embankment type with concrete core wall, separated into two wings by a massive concrete spillway 50 feet in height with crest at elevation 905. The overall length of the dam will be 3550 feet and the spillway will have a clear width of 260 feet giving it a capacity, with water level 7 feet above the crest, of 18,000 cubic feet per second or 208 cubic feet per second per square mile of drainage area.

The reservoir at spillway elevation will cover 2010 acres, will extend approximately 7 miles upstream from the dam and will have a maximum width of about one mile. Its available content above elevation 875 is 10 billion gallons. The safe yield is estimated at 0.43 million gallon daily per square mile of drainage area or 37.4 million gallons daily. This yield is adequate for the needs of the District until 1950. Opportunity for economical future increase of the supply available at this point to a total of 76.4 million gallons daily—sufficient for at least fifty years—is offered by reservoir development on the Upper Mahoning River with provision of a tunnel 8.7 miles long to deliver the additional supply into the Meander Creek Basin.

The highway changes to be made in connection with the reservoir include two viaduct crossings and two border roads, the overall lengths of which total 4.4 miles. One of the viaducts is to be a nine-span concrete arch bridge 894 feet in length while the other is designed as a six-span concrete beam bridge 260 feet in length.

The design of the purification plant provides for softening and rapid sand filtration. It is proposed to reduce the hardness of the water from an average of 135 parts per million to 100 parts or less. The plant will have initial rated capacity of 42 m.g.d. sufficient for a daily average supply of 32 million gallons with the distribution storage to be provided. The works are laid out for enlargement to capacity suitable for a daily output of 80 million gallons. Ordinarily the water will flow by gravity from the storage reservoir through the plant, but low lift pumps are included for occasional necessary operation.

The chemical house is designed for handling and storing of bulk chemicals and application through dry feed machines. The upper portion of this building will contain 10 concrete storage bins with total capacity of 700 tons, equivalent to six weeks supply of chemicals for a plant output of 40 m.g.d. Mixing chambers in four units equipped with motor driven agitators will provide a 20-minute mixing period.

Covered coagulation basins, of concrete groined arch construction, will furnish a settling period of 4 hours. Before passing to the filters carbon dioxide gas will be applied to the water to prevent lime incrustation. Two chambers adjacent to the coagulation basins will be provided for this purpose, furnishing a retention period of 10 minutes.

The filters will be in 14 units of 3 million gallons daily capacity each, constructed in a double row over concrete clear wells of one million gallons available storage capacity with pipe gallery between. A steel wash water tank of 130,000 gallons capacity will be enclosed in the filter building.

The pumping station is designed for use of steam-turbine-driven centrifugal pumping equipment. The initial installation will include one low-lift pump of 25 m.g.d. capacity for occasional operation and three high-lift units, two of 25 and one of 17.5 m.g.d. capacity, for service in pumping the supply to Youngstown and Niles in common. The initial boiler installation will include three stoker-fired units of 500 horsepower each, with provision of coal storage and equipment for mechanical handling of coal and ashes. The boiler room will also house the equipment for production of carbon dioxide gas.

The purified supply will be delivered to Youngstown in duplicate force mains, 36 inches in diameter and about 28,000 feet long, extending southeasterly from the pumping station to the distributing reservoir in the extreme westerly portion of the city. Two feeder

mains, each 36 inches in diameter and about 13,000 feet in length, will connect the force mains and the distributing reservoir with the existing large mains of the low service distributing system of the city.

The Youngstown distributing reservoir of 30 million gallons capacity will be of concrete groined arch construction.

The Niles force mains in duplicate will be 20 inches in diameter, one 10,000 feet in length and the other 15,000 feet long, connecting the pumping station with the present distributing system of the city. The Niles standpipe, replacing the present distributing reservoir, will be 60 feet in diameter and 70 feet in height with a capacity of 1.5 million gallons.

Upon completion of the proposed works the use of the existing filtration plants at Youngstown and Niles will be discontinued. The existing Youngstown pumping station will be retained as a booster station to draw water under pressure from the low-service mains and discharge to high-service. No repumping at Niles will be necessary.

With the execution of the recommended plan the member cities of the District will be provided with a water of high standard of quality —pure, attractive, wholesome and soft—meeting all modern requirements in a water supply. Important savings will be realized in the household and commercial use of water of such quality as compared with the existing unsatisfactory supplies, involving reduction in cost of soap and softening compounds, in depreciation of fabrics in laundering, in repair and replacement of plumbing and heating systems and in other items. Upon a most conservative basis of estimate, the total of such savings effected within the period of bond retirement will exceed the cost of execution of the plan. It may be mentioned that such savings form a rational basis of estimate of the benefits resulting from the improvement.

Associated with the writer in the direction of the engineering work of the District, G. Gale Dixon, Deputy Chief Engineer, has been in direct charge of office studies and design and C. B. Cornell, Field Engineer, has directed all field work.

ADVANTAGES OF DISTRICT PROCEDURE

Many valid arguments have been advanced in favor of District organization for solution of major water supply problems of important population centers. The growth of large cities is usually attended by growth and development of adjacent municipalities and

as a result the water supply problem becomes complex. Independent supplies are uneconomical and are frequently impossible to secure. In many instances the largest or outstanding municipality is placed at a disadvantage in shouldering the burden of investments for works adequate for all.

There is distinct advantage to be gained by joint action. Increased financial resources make larger and more satisfactory projects feasible, frequently at less cost than would be involved in individual action. Conflict between municipalities over water rights is eliminated; duplication of effort with the attendant expense is avoided; and all benefits of centralized control of construction and operation accrue.

The project of The Mahoning Valley Sanitary District has progressed sufficiently to warrant the belief that all the advantages claimed for District procedure will be realized by the member cities. The further progress of work of this District will no doubt be observed with interest by other cities having similar problems.

DESIGN OF PERFORATED PIPE STRAINER SYSTEM[1]

By J. W. Ellms[2]

The perforated lateral pipe and center manifold strainer system for rapid sand filters is one of the older systems in common use. It has certain advantages that commend it to engineers and, when properly designed, has generally given good results in practice. Some experimental work on the hydraulics of such a system, undertaken some years ago, may be of interest to engineers.

The experiments carried on in 1920 at Sacramento, California, by H. N. Jenks, Assistant Engineer of the Filtration Division of the City Water Department, were for the purpose of determining the proper relation between the size and spacing of perforations and the size and length of the lateral pipe in this type of underdrain system. The relative cross sectional areas of different sized perforations and of various sized laterals were studied thoroughly and some important deductions made. The conclusions reached by Mr. Jenks in this study were as follows:

1. The ratio of the length of the lateral to its diameter expressed in inches should not exceed 60.
2. The diameter of perforations in the lateral should be between $\frac{1}{4}$- and $\frac{1}{2}$-inch.
3. The spacing of the perforations along the lateral may vary from 3 inches, for a diameter of perforation of $\frac{1}{4}$ inch, to 8 inches for a diameter of perforation of $\frac{1}{2}$ inch.
4. The ratio of the total area of the perforations in the underdrain system to the total cross sectional area of the laterals should not exceed 0.5 for a diameter of perforation of $\frac{1}{2}$ inch, and should decrease to 0.25 for a diameter of perforation of $\frac{1}{4}$ inch.
5. The ratio of the total area of the perforations in the underdrain system to the entire filter area may be as low as 0.002 or 0.3 square inch per square foot of filter.
6. The spacing of the laterals may be as great as 12 inches for satisfactory diffusion, but is limited by the total head available.

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[1] Presented before the Central States Section meeting, September 21, 1926.

[2] Engineer of Water Purification and Sewage Disposal, Department of Public Utilities, Division of Water, Cleveland, Ohio.

7. The rate of washing may be varied from 6 to 36 inches per minute, or 0.5 to 3.0 cubic feet per square foot of filter per minute, provided the foregoing factors are used in the design.

The experiments at Sacramento were confined to the relation between the perforations and the laterals and showed that it was possible to obtain a fairly uniform discharge from the perforations, if there was a proper ratio between the sum of the cross sectional areas of the perforations and the cross sectional area of the lateral. It seemed to the writer that to make this investigation complete, it was desirable to go one step further and determine the proper relation between the sum of the cross sectional areas of the laterals and the cross sectional area of the header or manifold.

The Sacramento experiments indicated, also, that with a correct spacing of the perforations in the lateral, much longer laterals might be employed than have been the custom heretofore. In consequence, it occurred to the writer that, if a correct ratio of the sum of the cross sectional areas of the laterals to the header or manifold could be found, it might be possible to take advantage of the longer laterals by using one header or manifold in place of two, as is usually the case in large filter units, and utilize a much longer lateral that would extend from the center gutter to the opposite wall of the filter tank. If this could be done, it would be possible to place one main header under the bottom of the center gutter, and from this header or manifold extend long laterals across the entire width of each half of the filter bed, thus doing away with the usual manifold for each half of the filter tank.

The common practice in building large filter units of placing a manifold in each half of the tank is objectionable, in that it produces, on account of its width and depth, more or less of a dead area over each manifold that is not properly washed. The manifold as a rule stands several inches higher than the laterals. The placing of perforations or strainer nozzles in the top of the manifold or perforations in the bottom is a makeshift that does not produce the desired washing effect. The gravel bed must also be deeper on account of these center manifolds, and wash water rising from the laterals must meet more resistance than that which rises from the perforations or nozzles in the top of the manifold.

For these reasons it seemed desirable to learn whether the use of one large manifold, placed under the center gutter where it could not blanket any portion of the filter bed, and with long laterals ex-

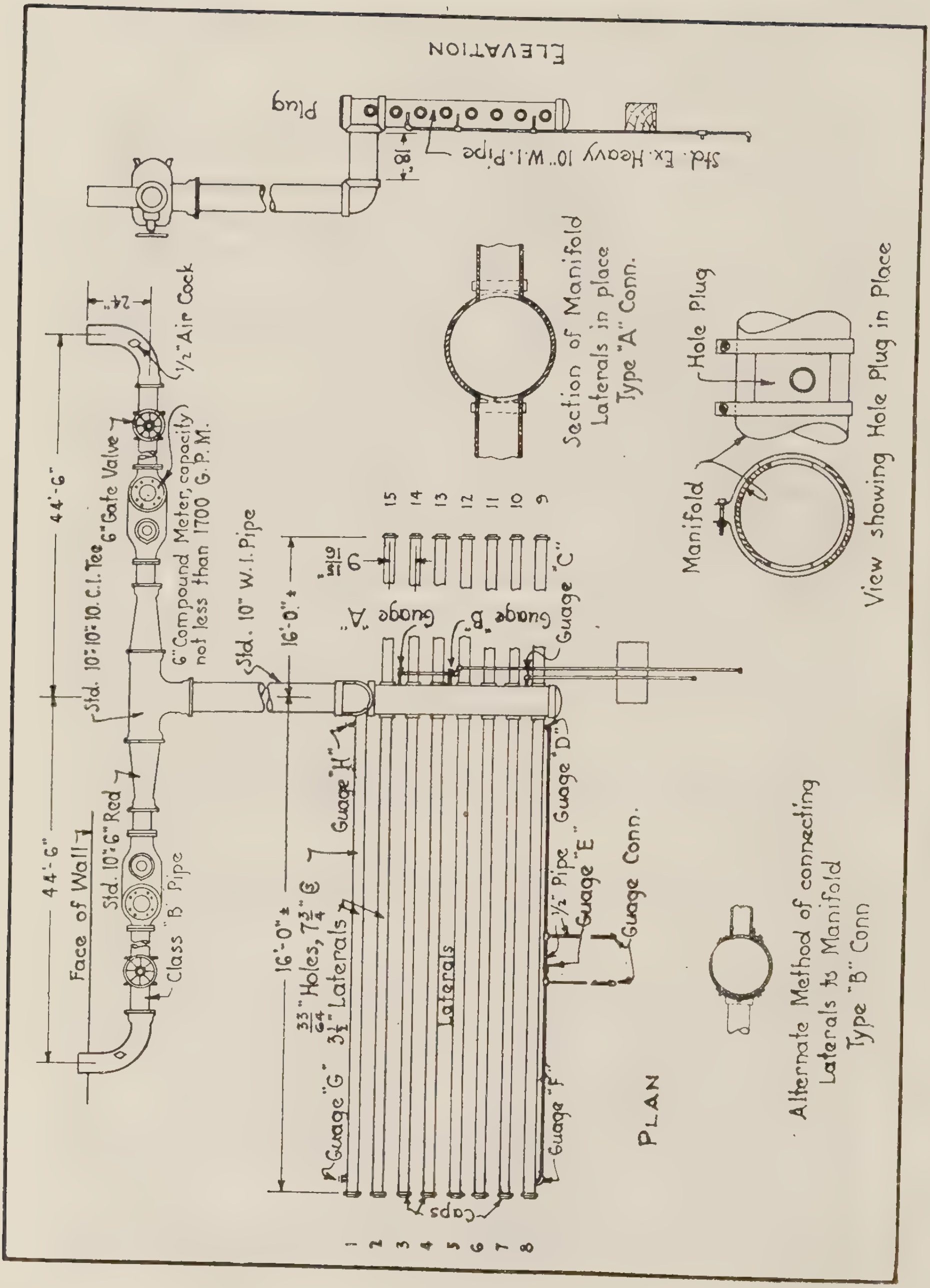


FIG. 1. EXPERIMENTAL STRAINER SYSTEM

tending across each half of the bed, was not feasible from the hydraulic standpoint. Such a change would result in decreasing the total amount of piping, and also in providing a better and more effective washing of the filter bed. With these objects in mind, the experimental strainer pipe layout was designed and constructed. It is shown in figure 1 and may be briefly described as follows.

TABLE 1

Total areas and ratios of areas

	DIAMETER	CROSS SECTIONAL AREA
	inches	*square inches*
1. Manifold or header	10	74.66
2. One lateral	$3\frac{1}{2}$	9.89
3. One perforation	$\frac{33}{64}$	0.209
4. Twenty-three perforations in one lateral-total area (23×0.209)		4.81

Ratios

	NUMBER OF LATERALS			
	A	B	C	D
For 14 laterals	0.48 to 1	1.85 to 1	0.90 to 1	0.54 to 1
For 12 laterals	0.48 to 1	1.60 to 1	0.77 to 1	0.63 to 1
For 10 laterals	0.48 to 1	1.33 to 1	0.64 to 1	0.75 to 1
For 8 laterals	0.48 to 1	1.06 to 1	0.51 to 1	0.94 to 1
For 6 laterals	0.48 to 1	0.80 to 1	0.39 to 1	1.26 to 1
For 4 laterals	0.48 to 1	0.53 to 1	0.26 to 1	1.88 to 1

Ratio A. Area of perforations in one lateral to cross sectional area of one lateral.

Ratio B. Sum of cross sectional areas of "n" laterals to cross sectional area of 10-inch diameter header.

Ratio C. Sum of cross sectional areas of perforations in "n" laterals to cross sectional area of 10-inch diameter header.

Ratio D. Cross sectional area of 10-inch diameter header to sum of cross sectional areas of "n" laterals.

The experimental strainer system consisted of a header or manifold 10 inches in diameter, and two sets of lateral pipes placed opposite each other in the same plane. The laterals were screwed into saddle flanges welded to the sides of the header and opening into the latter through a hole cut in the side of the 10-inch pipe. This method of

connecting the laterals to the header differs somewhat from the drawing, but was changed for construction reasons.

The laterals were each $3\frac{1}{2}$ inches in diameter, and spaced $9\frac{13}{16}$ inches apart on centers. The perforations in the laterals were $\frac{33}{64}$ inch in diameter, and were spaced on $7\frac{3}{4}$ inches centers. From the center of the header to the end of the laterals was approximately 16 feet. The laterals were turned so as to have the perforations at the top in order to measure the height to which the jets of water rose. Meters were provided for measuring the total flow of water for the different rates studied.

Gages for loss of head were provided at the four corners of the grid of laterals and also at different points on the main header. Gage boards placed at convenient points permitted reading the average height to which the water rose in the various tests.

In table 1 a tabulation of some of the basic data of the design for this experimental strainer system, as well as certain ratios used in the discussion of the results are presented.

The design follows the recommendations of H. N. Jenks as a result of his work in Sacramento in so far as the relation of the diameter and spacing of the perforations to the diameter and length of the laterals is concerned. By removing laterals, it was possible to change the ratio of the cross sectional area of the manifold to the sum of the cross sectional areas of the laterals. It was recognized that with 14 or 15 laterals in place the header would be too small to feed them; but by reducing the number of laterals, it would be possible to bring the ratios within reasonable limits. The ratios in the table for 14, 12, 10, 8, 6 and 4 laterals indicate the effect of reducing the number of laterals. The volume of water for rises of 20, 22, 24, 26, 27, 28, 29 and 30 inches per minute was reduced in proportion as the number of laterals were reduced in order to maintain a proper relation between the number of laterals and the area which they would serve. The area of filter nominally represented by full number of laterals was 172.4 square feet. The volume of water required for the different rates of washing varied from 77 to 432 cubic feet per minute, depending upon the number of laterals in operation.

In figures 2 to 7 inclusive, gage readings showing the height to which the water rose at the four corners of one-half the lateral pipe grid are shown. These gages, marked on figure, indicated the losses of head between the various points and showed that there was not a complete conversion of velocity head into static head. In general,

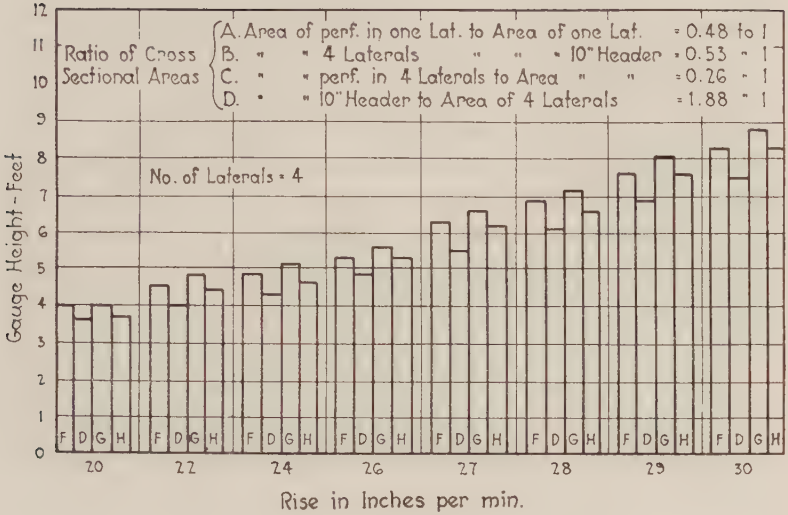

Ratio of Cross Sectional Areas
A. Area of perf. in one Lat. to Area of one Lat. = 0.48 to 1
B. " " 4 Laterals " " " 10" Header = 0.53 " 1
C. " " perf. in 4 Laterals to Area " " = 0.26 " 1
D. " " 10" Header to Area of 4 Laterals = 1.88 " 1
No. of Laterals = 4
Gauge Height - Feet
Rise in Inches per min.
F D G H
20 22 24 26 27 28 29 30
0 1 2 3 4 5 6 7 8 9 10 11 12

Fig. 2

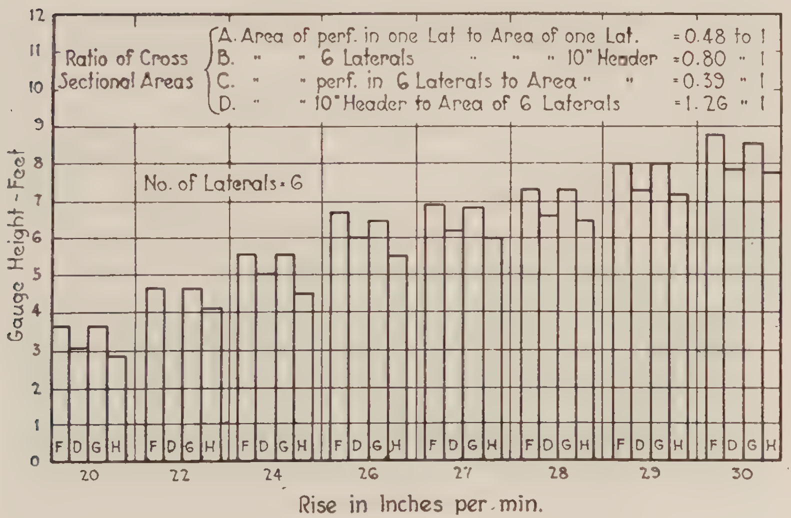
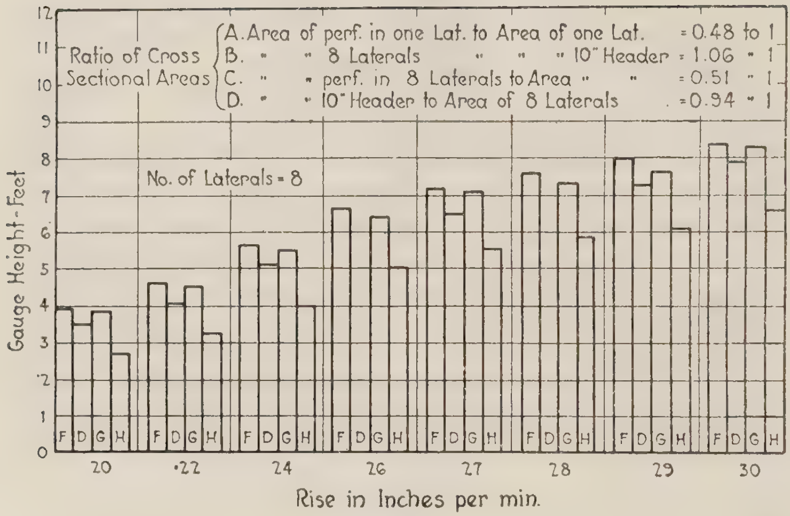
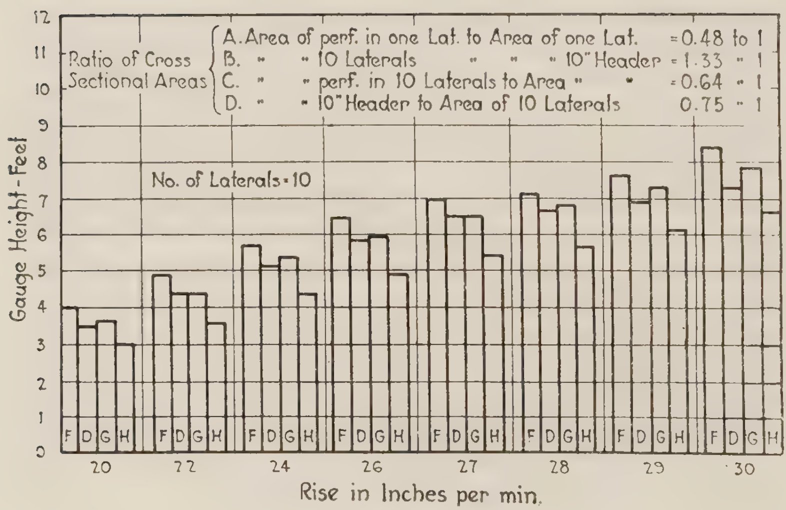

Ratio of Cross Sectional Areas
A. Area of perf. in one Lat to Area of one Lat. = 0.48 to 1
B. " " 6 Laterals " " " 10" Header = 0.80 " 1
C. " " perf. in 6 Laterals to Area " " = 0.39 " 1
D. " " 10" Header to Area of 6 Laterals = 1.26 " 1
No. of Laterals = 6
Gauge Height - Feet
Rise in Inches per min.
F D G H
20 22 24 26 27 28 29 30
0 1 2 3 4 5 6 7 8 9 10 11 12

Fig. 3



Ratio of Cross Sectional Areas
A. Area of perf. in one Lat. to Area of one Lat. = 0.48 to 1
B. " " 8 Laterals " " " 10" Header = 1.06 " 1
C. " " perf. in 8 Laterals to Area " " = 0.51 " 1
D. " " 10" Header to Area of 8 Laterals = 0.94 " 1
No. of Laterals = 8
Gauge Height - Feet
F D G H
20
22
24
26
27
28
29
30
Rise in Inches per min.

FIG. 4



Ratio of Cross Sectional Areas
A. Area of perf. in one Lat. to Area of one Lat. = 0.48 to 1
B. " " 10 Laterals " " " 10" Header = 1.33 " 1
C. " " perf. in 10 Laterals to Area " " = 0.64 " 1
D. " " 10" Header to Area of 10 Laterals 0.75 " 1
No. of Laterals = 10
Gauge Height - Feet
F D G H
20
22
24
26
27
28
29
30
Rise in Inches per min.

FIG. 5

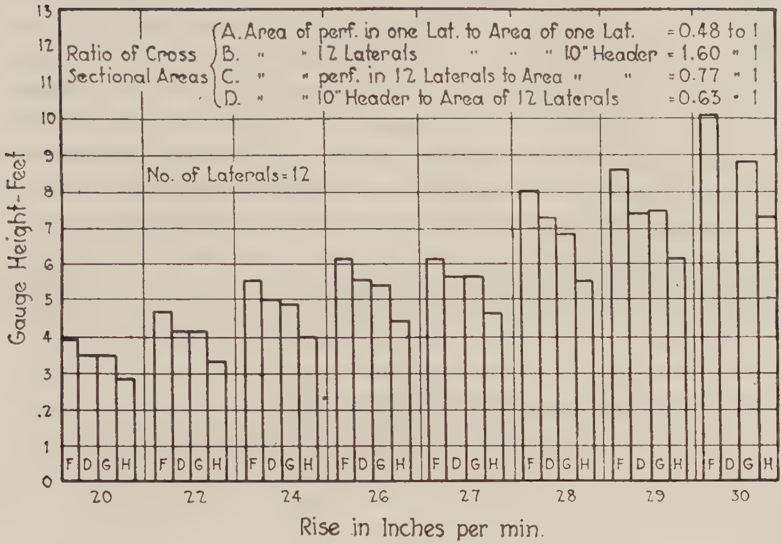

Ratio of Cross Sectional Areas
A. Area of perf. in one Lat. to Area of one Lat. = 0.48 to 1
B. " " 12 Laterals " " " 10" Header = 1.60 " 1
C. " " perf. in 12 Laterals to Area " " = 0.77 " 1
D. " " 10" Header to Area of 12 Laterals = 0.63 " 1
No. of Laterals = 12
Gauge Height - Feet
Rise in Inches per min.
F D G H
20 22 24 26 27 28 29 30

Fig. 6

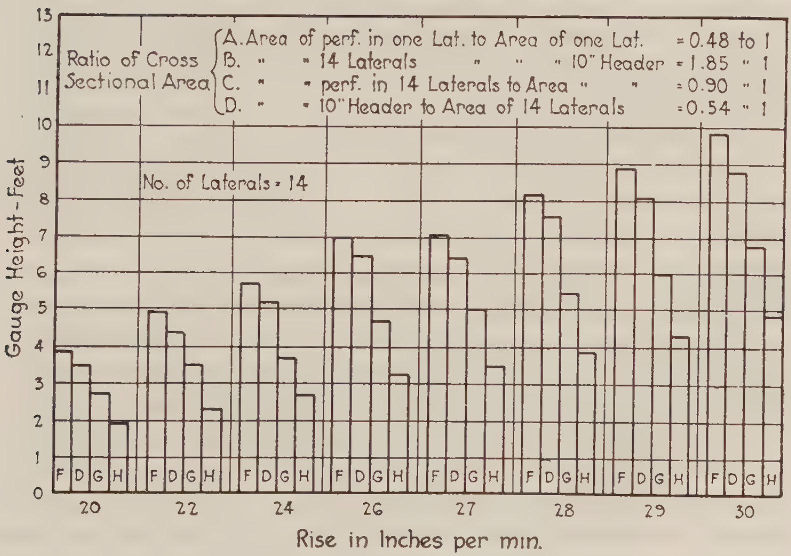

Ratio of Cross Sectional Area
A. Area of perf. in one Lat. to Area of one Lat. = 0.48 to 1
B. " " 14 Laterals " " " 10" Header = 1.85 " 1
C. " " perf. in 14 Laterals to Area " " = 0.90 " 1
D. " " 10" Header to Area of 14 Laterals = 0.54 " 1
No. of Laterals = 14
Gauge Height - Feet
Rise in Inches per min.
F D G H
20 22 24 26 27 28 29 30

Fig. 7

it appeared that the pressures were the lowest at gage H and the highest at gage F. Gages D and G showed pressures that were intermediate between pressures indicated by gages F and H with 14, 12, 10 and 8 laterals; but with 6 and 4 laterals in place, the pressures at G and H increased. The pressures at G equaled or even exceeded the pressures at F with 4 laterals, but were equal to or slightly less than the pressures at F with 6 laterals. With 4 laterals the pressures at D became the lowest of the four observed gage readings.

The uniformity of pressure in the grid is apparently greater the smaller the ratio of the sum of the cross sectional areas of the laterals is to the cross sectional area of the header, or ratio B. This is what

TABLE 2

Percentage variation from mean in the discharge of water from different numbers of laterals

	NUMBER OF LATERALS											
	4		6		8		10		12		14	
	+	−	+	−	+	−	+	−	+	−	+	−
For 20-inch rise	2.30	2.97	4.98	7.40	6.64	12.90	6.26	7.95	6.76	9.58	14.50	21.20
For 22-inch rise	4.30	4.75	4.80	7.37	5.80	10.39	5.80	8.42	7.30	10.05	15.00	21.20
For 24-inch rise	4.20	4.30	3.76	6.20	6.10	11.10	5.85	8.00	6.60	9.10	15.95	20.00
For 26-inch rise	3.32	4.37	2.13	3.35	5.64	8.75	6.27	7.74	6.95	9.15	15.27	20.80
For 27-inch rise	6.17	3.10	3.32	3.70	4.75	8.45	5.12	7.68	6.12	8.18	14.40	19.62
For 28-inch rise	3.71	4.55	2.73	3.05	4.72	8.55	4.56	6.72	7.90	10.26	15.20	20.50
For 29-inch rise	3.62	4.37	2.46	2.79	5.00	8.33	4.72	6.10	7.90	8.52	15.30	20.00
For 30-inch rise	3.45	4.30	3.14	2.89	3.87	7.95	5.60	5.75	7.72	8.44	14.80	19.50
Average........	3.88	4.09	3.42	4.60	5.32	9.55	5.52	7.30	7.16	9.16	15.05	20.35

might have been expected, since by decreasing the number of laterals to be fed, and retaining the same size of feeder (header), the velocity in the header was materially diminished, and a better conversion of velocity head to static head was effected. The actual variation in pressures at the different gages may be readily read from the graphs. For 4 and 6 laterals, the average range in pressures was 0.9 foot, with minimum variations of 0.3 and 0.8 foot, and maximum variations of 1.3 and 1.2 feet, respectively. When the B ratio increases, however, pressure differences become markedly greater, so that when 14 laterals were used, the average variation was 3.6 feet with a minimum and maximum range of 2.0 and 5.0 feet, respectively. The variations are, as a rule, greater the higher the velocity of the wash water.

Since the discharge varies as the square root of the head, the figures in the table which follows were calculated to show the percentage variation above and below the mean as determined from the gage readings. The fluctuations in the discharge varied on an average for all rates of wash water rises from 3.42 to 15.05 per cent above the mean, to 4.09 and 20.35 per cent below the mean. The discharges from the four laterals or from the six laterals were more uniform than when a larger number of laterals were in use.

It is interesting to note that the variation in the losses of head in the header (10-inch diameter pipe) averaged 0.2 and 0.36 foot, respectively, between gages *B* and *C* where 4 and 6 laterals were used, and with minimum and maximum variations of 0.1 and 0.5 foot. While the distance between the gages was short, it would seem to indicate that no material loss of head in the header need be anticipated, provided correct ratios of header to laterals are installed.

A comparison of the experimental strainer system with the one in actual use at the Division Avenue Filtration Plant of the City of Cleveland reveals some interesting relations in connection with their basic design data. At this plant the perforated pipe system is served by a four section center manifold in each half of the filter tank. Each manifold section has a variable cross section, being larger at the center and diminishing in size toward the end. At the center of the section the manifold has a cross sectional area of 135.52 square inches.

There are 384 laterals each with an effective length of 6 feet, and serving a filter area of 1451.4 square feet. These laterals are 2.5 inches in diameter, spaced $6\frac{5}{64}$ inches apart, and with $\frac{1}{4}$-inch diameter perforations which are spaced $2\frac{1}{4}$ inches apart and staggered. There are 33 perforations per lateral and in addition 1120 perforations in the bottom of the manifolds. The area of the perforations in one lateral is 1.62 square inches, and the area of the cross section of the lateral is 4.91 square inches.

Using these figures and the ratios as defined previously, the relations of the perforations, laterals and manifolds to each other for the Division Avenue Filter Plant design are as follows:

Division Avenue Filter Plant Strainer System, Cleveland, Ohio

Ratio A is equal to 0.331
Ratio B is equal to 0.873
Ratio C is equal to 0.308
Ratio D is equal to 1.15

Note: In ratios *B*, *C* and *D* the holes in the manifold sections have been disregarded.

Comparing these ratios with those of the experimental strainer system, we find that "Ratio A" of the latter is larger or 0.48 to one. We also find that the ratio of the length of the lateral to its diameter or L/D, as expressed by Jenks of Sacramento, is 49 in the experimental strainer system (and which is in accord with his findings), as against L/D equal to 29 in the Division Avenue Filter Plant design.

It should also be noted that, if we disregard the holes in the manifold in the Division Avenue Filter Plant design, the ratios B, C and D all fall within the limits of the experimental system ratios where 4 or 6 laterals were used. The holes in the manifold itself would not make much of a change in the ratios even if they were included.

GENERAL CONCLUSIONS

While it is recognized that the experiments made do not give ideal results, nevertheless they clearly indicate the limits which should not be exceeded. It is plainly apparent that the sum of the cross sectional areas of the laterals should be at least twice the sum of the cross sectional areas of the perforations in the laterals; and that the manifolds feeding the laterals should have cross sectional areas from 1.75 to 2.00 times the sum of the cross sectional areas of the laterals which they feed in the washing process. These experiments also confirm the investigations of Jenks in Sacramento in showing that longer laterals of the proper diameter may be used and still produce a good distribution of the wash water. This condition offers an excellent opportunity to employ only one manifold for both halves of the filter tank by placing it under the center gutter, thus reducing the number of manifolds and providing for a gravel and sand bed of uniform thickness throughout. This design has already been successfully incorporated in one filter plant having two-million-gallon filter units; but it is obvious that it can also be applied to the design of units of even twice this capacity with equal success, since the lengths of the laterals in the experimental strainer system were sufficient to serve easily one-half a filter unit of four million gallons daily capacity.

SANITARY SAFEGUARDS IN WELL CONSTRUCTION[1]

By W. Scott Johnson[2] and H. A. Buehler[3]

Adequate supervision and inspection for the purpose of assuring essential sanitary safeguards, necessarily installed during well construction, have in the past been difficult to secure in Missouri. As a guide for specifications covering such construction a comprehensive report, on the sanitary protection for wells, was submitted by the Committee of the Conference of State Sanitary Engineers on the Sanitary Control in the Development of Ground Water Supplies and adopted in 1925 at the Louisville, Kentucky, meeting. However, specifications covering all possible conditions encountered would not be practical and each well requires individual expert attention during its construction period. Experience indicates that, granting the individuals in charge of drilling operations are thoroughly awake to the importance of proper sanitary well construction, there is still the factor of widely varying geological conditions encountered in Missouri, which demand expert technical supervision in order to assure safe and economical results. The method of securing this, through coöperation of the State Geologist and the State Board of Health, is the subject of this paper.

GROUND WATER CONDITIONS IN MISSOURI

Practically all the potable ground water supplies in Missouri are located in the southern half of the state in two areas known as the Atlantic Coastal Plain and the Ozark Plateaus. The Atlantic Coastal Plain, comprising a small area in the extreme southeast corner of the state, formerly contained considerable swamp land which has been drained. The water supply is secured from a shallow underground flow which is protected by a layer of fine sand frequently supplemented by a sealing layer of shale. This water is of excellent quality and the subsurface conditions are such as to assure proper well construction with little or no difficulty.

[1] Presented before the Chicago Convention, June 9, 1927.

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[3] State Geologist, Jefferson, Mo.

Throughout the Ozark Plateau region, the geological conditions are very different and the water supplies in this section are obtained principally from deep wells drilled in rock. This region is one of the oldest uplifts in this country. The sandstone which supplies the most satisfactory water supply is overlaid by several hundred feet of limestone badly fissured and shattered. Contaminated surface water gains access through sink holes and outcroppings to great depth due to these conditions. Indicative of this condition some of the largest springs and caves in the United States are located in this territory. There are on record numerous accounts of substances of a surface origin, such as sawdust and lubricating oil, traveling for miles through underground channels before appearing again at the surface.

A striking example of the fissured and open condition of the limestone strata in this territory is illustrated by the experience of a city of 3000 population with its water supply. Extremely careless methods of sewage disposal had resulted in the discharge of the overflow of septic tanks into abandoned wells and sink holes for many years. The two city wells were 850 and 1300 feet deep respectively, and each was cased 600 feet, a third well was drilled 2690 feet deep and cased to a depth of 1050 feet. Bacteriological analyses of water from these wells showed intermittent contamination. A careful study was made regarding the construction and protection of these wells for the purpose of determining the cause of this contamination. However, no sanitary defects were discovered, and it was concluded that fissures and channels in the limestone were carrying the heavy pollution from the shallow strata under the city to the source of the deep well water supplies. The only solution of the difficulty was purification and this was immediately provided for by the city.

NECESSITY OF SUPERVISION DURING CONSTRUCTION

Many well drillers, engineers and the public at large have assumed and have firmly established the erroneous but popular idea that water from underground sources is always pure. This view has become particularly dangerous from the standpoint of public health due to the increasing pollution of underground strata and the growing demand of small towns for municipal water supplies developed as cheaply as possible. A well supply is the most feasible solution, and the necessary tendency toward economy almost invariably results in as short a casing as possible. In order to secure a sufficient quantity of water, often guaranteed by the driller, one natural tendency

is for developing the largest yield possible and against properly sealing the casing to shut out the contaminated water from shallow strata.

An investigation of the ground water supplies in Missouri by the State Board of Health indicated that many wells had not been properly constructed and were consequently subject to contamination. This condition was of particular danger in the Ozark Plateau region where insufficient casing or failure to seal the same properly at the bottom constitutes a ready avenue for the entrance of pollution. As a matter of fact there are records of more epidemics occurring from ground water supplies in the State in the past than from surface water supplies. The fact that a well improperly constructed from the sanitary standpoint has given no cause for alarm over a considerable period of time is no assurance of its continued innocence. Pollution of a poorly constructed well from subsurface sources may be indefinitely postponed or of intermittent character so that ordinary routine laboratory analyses by the State Board of Health will not always be of value in indicating the danger. One particular case of a town of 2000 population, which has been using a well supply for a number of years, is a striking illustration of this condition.

A survey of the well supplying this town, made by an engineer with the State Board of Health, revealed that the casing was only 16 to 20 feet deep or just to the first rock layer. Further investigation revealed that this first rock cap outcropped only a short distance from the well and that in addition the sourrounding region contained many sink holes. Bacteriological analyses of the water showed the presence of B. coli. On the basis of this information the State Board of Health recommended that the water be disinfected with chlorine at once by means of a temporary machine until the well could be properly reconstructed or arrangements made for permanent purification. The danger from surface contamination of this well was concurred in by a subsequent report of the State Geologist. However, the emergency chlorinator was not properly constructed and the dose control was inadequately supervised. Several weeks later a severe epidemic of dysentery broke out among the citizens. Over 125 cases occurred and the city physician reported the epidemic as typically water-borne. Shortly following the epidemic during a period of heavy pumping the well water began to show muddy and this condition became worse and continued as long as the well was used. The pollution of this well was undoubtedly caused by water of recent surface origin gaining entrance below the shallow casing.

Following these difficulties the city drilled a new well properly constructed from the sanitary standpoint with a casing 550 feet deep and tightly sealed. The analyses of samples of water from this well have consistently indicated water of excellent quality and of course free from turbidity.

In seeking to secure satisfactory well construction from the sanitary standpoint, various specifications have been formulated. Of these the one proposed by the State Conference of Sanitary Engineers is probably the most thorough. However, while these specifications are entirely satisfactory in securing proper well construction with regard to many sanitary features, they are inadequate as regards others. It is possible by means of specifications to secure a casing of certain weight and material and assure satisfactory construction at the well top to eliminate surface contamination. However, these precautions are of small avail if the casing is not set sufficiently deep and tightly sealed so as to shut out the contaminated water following solution channels in the subsurface limestone.

Specifications covering these particular features of well construction have not alone been found entirely satisfactory for several reasons. It is not safe or economical to specify one certain depth for casings to apply under all conditions. In Missouri the satisfactory depth of casing has varied from 100 to 600 or 700 feet, with no assurance that this may not be decreased or increased under conditions to be encountered in the future. This part of well construction is not subject to inspection after completion and it is extremely difficult, if not impossible, to gain information concerning it after the well is complete. Presupposing a desire on the part of those concerned to carry out the intent of the specifications, the adequate interpretation of it under varying geological conditions encountered requires a specialized technical knowledge of geology, not possessed by the average engineer or well driller. Consequently, it has proven impossible in many instances for the State Board of Health to have adequate assurance of satisfactory well construction through the agency of specifications alone.

METHOD OF SECURING SATISFACTORY WELL CONSTRUCTION

In order to overcome this difficulty in the sanitary construction of well water supplies a coöperative agreement was entered into between the State Board of Health and the State Geologist that has proven most successful.

Specifications have been prepared covering the sanitary features of wells drilled in rock and the installation of well pumping machinery. All engineers are required to include these in specifications for the construction of municipal water supplies secured from wells. (See appendices A and B.)

In accordance with an agreement, the State Geologist is informed concerning a proposed well water supply and the driller is required to send a written notice to that office at least one week before operation is started. This gives the State Geologist an opportunity to advise with the driller concerning the probable conditions to be encountered and also to supply a set of sacks for drillings and a drill record book. After drilling operations are begun the driller is required to secure cuttings from every screw, place same in sacks, label and send at once to the State Geologist. Also, all information concerning openings, fissures or soft or broken ground encountered is reported. From these data the State Geologist determines the depth at which it will be necessary to place the casing in order to exclude water of recent surface origin following solution channels and fissures in the rock. When the proper depth for setting the casing has been reached a field representative of the State Geologist inspects the job, supervises the sealing of the casing and checks the tightness of seal, as required by the specifications. After completion of the well all samples of cuttings secured after casing and the complete record book of log are forwarded to the State Geologist, who correlates same and furnishes the owner and the State Board of Health with a copy of the completed log of the well.

Upon completion of the entire job, including installation of the pump, etc., a final inspection is made by an engineer from the State Board of Health to check for approval the sanitary features of the well top construction, including proper drainage of pit, if same is provided for, height of well casing above pit or pump room floor, well casing material, and the effectiveness of seal between drop pipe and casing (see appendix B). At this inspection samples are collected for bacteriological analyses at the State Board of Health Laboratory and for complete chemical analysis by the State Geologist.

RESULTS

Since the inauguration of this coöperative plan for securing better sanitary safeguards in well construction, 25 municipal wells have been drilled and a large number of private and institutional wells.

The engineers in charge of work have coöperated from the first and with few exceptions expressed an appreciation for this service. Well drillers readily saw the value of the information and advice available with regard to geological features encountered in drilling wells and the opportunity which this affords of eliminating much guess work. For the past year and a half the routine procedure has operated with exceptional smoothness and satisfaction to all concerned. As more information from well logs is tabulated the State Geologist is able to give more accurate and detailed information regarding the construction necessities for proposed well supplies in the neighboring vicinity.

Still more important, the bacteriological results from these wells indicate water of excellent sanitary quality, with one exception. It is of interest to note that in this one instance it was foreseen before starting work that unusual geological conditions would in all probability cause the well supply to be unsatisfactory. In addition the accurate construction information secured with regard to these wells affords a basis for dealing with any situation which may arise in the future regarding either the quality or quantity of the water supply.

Although there are other numerous advantages which result from the operation of this plan, it is the opinion of those concerned that the improvement in the sanitary features of well construction which results in the assurance of safer water supplies more than warrants and adequately justifies the work involved.

APPENDIX A

SPECIFICATIONS COVERING SANITARY FEATURES OF WELLS DRILLED IN ROCK

1. *Samples of cuttings.* At least one week before starting to drill the well, the driller shall send a written request to the State Geologist, Rolla, Missouri, who will furnish a set of small sacks and a drill record book. The well driller shall save a sample of cuttings from every screw and place same in the sacks properly labeled, and forward same each day to the State Geologist.

2. *Casing.* The well shall be cased with a screw joint steel or wrought iron pipe installed in a watertight manner. The State Geologist will recommend the depth of casing advisable to effectively shut out contaminated surface water based upon available records. The casing shall be extended to at least this depth and deeper if necessary so as to case off all openings or soft or broken ground.

Where the water encountered is known or found to be corrosive, special provision shall be made to protect the casing from corrosion by a method approved by the State Board of Health; the contractor to receive extra compensation for same in an amount agreed upon in writing prior to undertaking the work.

The well casing shall be extended to a point from four to six inches above the elevation of the finished pump room or pump pit floor, and shall be provided with a thread at the top.

3. Seal. A satisfactory seal shall be made or installed at the bottom of the casing, by one of the following methods:

a. Setting the bottom of the casing on a shoulder in the well made by reducing the size of the drill hole, and sealing with cement grout, a lead packer or drill cuttings of a cementing character.

b. Driving casing into clay, shale or similar sealing formation.

c. Installing an expanding rubber packer.

The seal shall be tested by bailing out the drill hole and making sure that there is no leakage into same over a period of forty-eight hours. When no appreciable amount of water has been encountered up to time of sealing, at least 1000 gallons of water shall be run into the annular space on the outside of the casing to test the seal.

4. Water analysis. Where a waterbearing stratum, furnishing the required volume of water, is encountered at a satisfactory depth, samples of water shall be collected at the end of the pumping test run and submitted to the State Geologist or private chemist for complete chemical analysis, including the iron, manganese, and hardness content, to determine the suitability of the water for a general city supply.

5. Records. The driller shall note in the drill record book the location and depth of any openings or soft or broken ground encountered, together with complete information on the depth of casing, method of sealing same, and result of test of seal.

Immediately on completion of the well, and prior to completion if requested, the driller shall forward all samples of cuttings and the drill record book to the State Geologist, who will correlate same and furnish the owner with a copy of the completed log of the well.

6. Approval. These specifications shall be carried out in a manner satisfactory to the State Board of Health, before this portion of the work is accepted.

APPENDIX B

SPECIFICATIONS COVERING SANITARY FEATURES IN THE INSTALLATION OF WELL PUMPING MACHINERY

A. The use of a well pit or subground-level pump room shall be avoided wherever practicable on account of the possibility of stoppage of the drain or ejector and neglect to replace the well top seal after making repairs.

B. Where the pump is installed without a pit.

1. The pump shall be installed on a concrete base of sufficient height to permit the outside casing to extend at least 4 inches above the pump room floor, and to enable the installation of a suitable connection as noted under B–2

2. The annular opening between the outside casing and pump column shall be closed by means of a suitable watertight connection which will effectually prevent waste water, oil, insects or other contaminating material from entering the well.

C. Where the pump is installed with a pit or in a pump room below the ground level.

1. The sides and bottom of the pit or pump room, below the ground level, shall be constructed of watertight concrete. The pit shall be left uncovered to permit easy inspection by the pump operator, and shall be surrounded by concrete curb at least 6 inches high and a pipe railing.

2. The annular opening between the outside casing and pump column shall be closed by means of a watertight connection capable of withstanding for twenty-four hours, without leakage, the water pressure resulting from complete filling of the pit with water. The types of connections approved are given below in order of preference.

a. An all flanged or threaded connection.

b. A stuffing box connection.

c. Metal to grouted cement connection with suitable gasket (not rubber); to be used only when joint carries weight of pump and is rigidly supported to prevent vibration.

Any vents provided for the well shall be extended by a pipe with screw or flange connections to a point above the floor level. A return ell shall be screwed on the upper end of this pipe, and screened.

3. Drainage shall be provided for the pump pit or pump room by one of the following methods:

a. By means of a drain consisting of a sewer pipe, not less than 6 inches in diameter, with cemented joints, installed in a straight line and on an even grade of not less than 0.6 foot per 100 feet, with a concrete bulkhead at the outlet to insure an open discharge at all times; provided that under no conditions shall this drain receive sewage, or be connected to a sewer, and that the bottom of the pit so drained shall be above the high water level in any adjacent watercourse.

b. By means of a pump or ejector drawing from a sump of not less than 12 cubic feet capacity situated so as to collect all waste water. This pump or ejector shall operate automatically or be connected to some moving part of the pump head, so as to operate continuously with this pump, and shall discharge above the pump room floor level into a suitable drain at a point safely removed from the pump pit or pump room.

4. The bottom of the pit or pump room shall be sloped away from the top of the well casing toward the drain or sump with sufficient grade to insure ready flow. The well casing shall extend four to six inches above the pump pit floor and at least six inches difference in elevation shall be provided between the top of the well casing and high water level in the sump.

d. A separate pump column, suction or discharge pipe shall be installed inside the well casing in all instances, whether the well is to be pumped by suction, air lift or deep well pump.

E. These specifications shall be carried out in a manner satisfactory to the State Board of Health of Missouri, before this portion of the work is accepted.

ELECTRIFICATION OF UPPER PUMPING STATION, AUBURN, N. Y.[1]

By A. J. Adams[2]

Auburn, in the center of the Finger Lakes Region, has a population of approximately 37,000 people. It is situated on both banks of the Owasco Outlet about 2 miles northerly from the foot of Owasco Lake.

A more ideal residential city would be difficult to find and its diversified manufacturing interests aid materially in maintaining the stable business conditions which Auburn has enjoyed for so many years. The city has shown no phenomenal growth during the past few decades, the census reports showing practically constant figures. Furthermore no rapid increase in population is expected in the near future.

The city obtained its first public water supply about 1867 when the Auburn Water Works Company was inaugurated as a private corporation. In 1894, the Board of Water Commissioners was created for the purpose of supplying to the city a mode of acquiring and operating its own water supply. The property of the private company was subsequently purchased for the sum of $425,000.00.

The plant transferred at that time consisted of an upper pumping station at the lake with an intake, extending but a short distance from the station, and a line, used as a syphon, running to the lower or pressure station located at the state dam. This pipe is approximately 9000 feet in length and 24 inches in diameter. There were some 20 miles of water mains, mostly of concrete construction, of which only about 25 per cent were even as large as 4-inch. There were 303 hydrants of which only 39 were two-way.

The Board of Water Commissioners operated the Department until January 1, 1921. In the twenty-six years of their administration, this modest beginning has developed into a modern plant which will compare favorably with any water system for a town of equal size in the country.

[1] Presented before the New York Section meeting, May 5, 1927.

[2] Chief Engineer and Superintendent, Water Department, Auburn, N. Y.

Improvements under the Commissioners include the replacing of the short, 24-inch intake with a new 36-inch pipe extending 1875 feet from the upper station which is itself 1100 feet from the shore. A new suction well, 15 feet in depth below the surface of the lake, was constructed and the influent was protected by a screen chamber.

The upper station was practically reconstructed and a new Snow pump and boilers added. At the lower station, a new, ten million gallon, R. D. Wood pump and engine with a battery of three boilers were installed, which necessitated a large addition to the buildings. The 20 miles of mains have been relaid and additional lines constructed until now we have a well gridironed distribution system, 70 miles in length, of which very few are smaller than 4 inches in diameter.

A modern, slow sand, filtration plant having a net area of 1.59 acres, together with a 3 million gallon, pure water reservoir, was placed into service in 1920. The cost of this construction was approximately $350,000.00. In addition to these improvements, the city has been 100 per cent metered.

In 1920, the city government was changed from the Mayor-Aldermanic plan to the Commissioner-Manager form known as "Plan C." On January 1, 1921, the Board of Water Commissioners was abolished and the water department taken over by the city government with the city manager as administrative head of the department. No other change was made in the operating personnel of the water department.

Early in 1924, the firm of Hazen and Whipple, the consulting engineers who designed the filtration plant, were engaged to make a survey of the water department and to report their findings to the city manager.

In their report, of first importance was the recommended construction of a storage reservoir in the distribution system to hold at least a 24 hour supply. This is a prime requisite in a direct pumping system such as is employed at Auburn.

At the lower station, we have sufficient water power which would be available for the entire pumping operations for about 9 months of the year in connection with such a reservoir. However, at the present time, boilers are fired, steam pressure up and reserve equipment hot at all times for use in an emergency. Thus much coal is burned which does no actual work.

Continuing their recommendations, the consulting engineers

suggest the installation of two new, Diesel engine driven centrifugal pumps, each capable of carrying the full domestic load, for use at the lower station when water power is low and for emergencies. They suggested also a new water wheel with direct connected electric generator, together with a transmission line to the upper station to operate electrically driven, centrifugal pumps proposed for that station. As a reserve for the upper station in case of trouble with the water driven generator, an electric generator to be driven by the Diesel engines was proposed. The estimated cost of all of these improvements, to make the system safe, was a little over $400,000.00.

In working out the operating costs under the proposed scheme, it was shown that the economies affected would practically carry the fixed charges on the proposed new investment. In conclusion, they recommended that the entire program be carried out, but if this could not be accomplished, that the fulfillment of any part of the program would show its advantages.

As the electrification of the upper station, purchasing power from the local power company, had been discussed for some time, it was decided for the present to install the electrically driven units at this station obtaining the current from the power company. This was the least expensive part of the program which would show a return upon the investment.

Of the two steam driven pumps at the Lake Station, the antiquated Holly pump and engine were practically worthless while the 10 million gallon Snow pump, together with the two, 100 horse power boilers, were in fair condition. It was proposed to replace the Holly pump and engine with equivalent electrically driven equipment, holding the Snow pump and boilers intact for reserve.

After careful study of the raw water requirements at the filter plant, the following average yearly operating rates were worked out applicable for some years at our anticipated growth:

	hours
$4\frac{1}{2}$ million gallons per day	1,664
5 million gallons per day	2,920
$5\frac{1}{2}$ million gallons per day	1,566
6 million gallons per day	1,570
7 million gallons per day	1,040

This variation in pumping rates is necessary to keep the head of raw water fairly constant over the sand beds at the filter plant. The suction lift from the surface of the lake to the pump room floor

averages 7 feet including friction. The static head on the discharge line is 29 feet. Between the filter plant and the upper station is a long line of 24-inch transmission main which develops considerable friction loss under high rates of flow.

On the basis of the above mentioned pumping rates, the total dynamic heads under which the pumps would operate were determined as follows:

	feet
At 7 m.g.d. rate	60
At 6 m.g.d. rate	54
At $5\frac{1}{2}$ m.g.d. rate	51
At 5 m.g.d. rate	49
At $4\frac{1}{2}$ m.g.d. rate	$46\frac{1}{2}$

As before mentioned, it was decided to replace only the old Holly pump at this time. After careful consideration, it was determined that better operating conditions could be obtained by installing two units for the variation in our rates. Consequently, proposals were asked—for one, 7 million gallon, centrifugal pump direct connected to a slip ring, variable speed motor for operation under the 7 to $5\frac{1}{2}$ million gallon rates and also one 5 million gallon pump likewise direct connected to a slip ring variable speed motor for use at the 5 million gallon rate and lower.

To avoid keeping a boiler under fire with steam pressure sufficient to start the Snow steam driven pump for use in case of serious failure of the electrical supply, we decided to install on one end of the shaft of the larger pump a gasoline engine of sufficient power to drive the pump at capacity and also capable of increasing the pump speed to obtain the required total capacity under the Underwriters requirements, when running the pump together with the steam driven unit. For priming the centrifugal pumps, Nash Hytors were chosen, one direct connected to an electric motor and the other to a gasoline engine.

Under the proposed scheme, we considered that we would have an extremely flexible combination. Either of the two electrically driven centrifugal pumps could be operated or both together as the occasion demanded. In case of failure of the electrical supply, the gasoline driven engine could be used as a prime mover and as a last resort, we could fall back upon the steam driven equipment which was to be left in place.

In answer to our advertisement for proposals, we received propo-

sitions from 12 pump manufacturers which resulted in very keen competition. In canvassing these proposals, consideration was given not only to the first cost of the equipment, but also, using the overall efficiences furnished with the bids, the probable annual operating costs under each proposal were worked out. Under this method of tabulating the bids, the proposal of the Turbine Equipment Company was accepted as the most advantageous to the city. Under their contract, De Laval centrifugal pumps with General Electric motors were furnished and a Buffalo gasoline engine provided as the standby.

All changes to the suction and discharge piping were made, concrete foundations constructed and the entire installation of the equipment carried out by the regular employees of the water department. To provide one unit in reserve at all times, the 5 million gallon pump was set up on a temporary foundation, connected to the mains and supplied with energy, ready for operation, before the old Holly pump was dismantled.

Early in August, 1926, the entire installation was completed and, in October, an acceptance test was made on the pumps in the field with the result that the guarantees were amply fulfilled. The larger pump showed an overall efficiency of 73½ per cent while the 5 million pump gave 72 per cent.

Primarily, the motive for the installation of these new pumps was the replacing of worn out machinery and the improvement in reliability at this station. As a result of these improvements, we have eliminated seventy-five points of the deficiency rating established by the National Board of Underwriters. Also, we believe that a material saving will be shown in the annual operating costs for this plant.

For the past six years under steam driven operation, the annual cost of this station has averaged $19,900, exclusive of repairs. With the electrically driven equipment in service, our operating costs are running about $1450 per month or $17,500 per year. These costs will be reduced by a further saving of $1575 per year in labor as soon as the engineers are thoroughly familiar with the new equipment.

Table 1 shows the first cost and installation charges for this improvement.

Under the present city manager plan of government for the past six years, the water department revenues have increased from $137,000 to $156,700 with an increase in operating costs of only

from $113,400 in 1920 to $114,800 in 1926. During this period there has been practically no increase in population and the water rates have not been advanced.

TABLE 1

Cost data on new pumping equipment

Switch board and installation	$2,261.99
Pumps, motors, engines, etc	7,853.33
Cast iron pipes, specials and fittings	1,932.97
Gates and valves	1,790.20
Freight and cartage	650.57
Foundation materials, etc	484.34
Machine work and labor	242.74
Removing old equipment, materials	100.69
Engineering expense	75.39
Printing and advertising	38.30
Pay rolls	1,504.81
Total	$16,935.33
Credits, return of materials, sale of materials, junk, etc	638.86
Net cost of improvement	$16,296.47

As of January 1, 1927, the outstanding bonded indebtedness of the Department was $237,000. With the reserve in the sinking fund of $43,367 our net debt is $193,633. The total book value of the plant, not considering allowance for depreciation, is $1,600,000.

CONSTRUCTION AND OPERATION OF THE MEMPHIS WATER WORKS[1]

By James Sheahan[2]

The city of Memphis has a commission form of government established January 1, 1910. The present members are: Rowlett Paine, Mayor and Commissioner of Public Affairs and Health; Thos. H. Allen, Vice-Mayor and Commissioner of Fire and Police; Charles R. Shannon, Commissioner of Accounts, Finances and Revenues; Harry N. Howe, Commissioner of Streets, Bridges and Sewers, and Horace Johnson, Commissioner of Public Utilities, Buildings and Improvements. The population is estimated at 200,000. The United States Census in 1920 showed 162,351.

The leading industries are the manufacture of hardwoods and its products, cotton and its products and assembling of automobiles. It is also an important distributing center for merchandise.

There are approximately 400 miles of dedicated streets, 125 miles of which are hard surfaced, 200 miles graveled and the rest unimproved.

The water supply was purchased by the city in 1903. The operation of the water department is under the supervision of a board of three commissioners appointed by the Mayor, one every two years for six-year terms. The board appoints a general superintendent, secretary and resident engineer. The general superintendent is in responsible charge of operation. The present commissioners are F. G. Proutt, Chairman, Jno. M. Dean, Vice-Chairman and W. W. Mallory. The officers are James Sheahan, general superintendent; Sanford Morison, secretary, and Carl E. Davis, resident engineer.

The parkway pumping station is divided into a main pump room, a boiler room and a machine shop. The walls are brick; the roof is concrete supported by steel girders. The main floor is concrete covered with tile. The basement floor is also concrete.

[1] Presented before the Kentucky-Tennessee Section meeting, January 21, 1927.

[2] General Superintendent, Water Department, Memphis, Tenn.

WATER SUPPLY AND DISTRIBUTION SYSTEM

The pumping capacity of the Memphis water department is over 60,000,000 gallons per day. Normal conditions require the use of only one-half of this, keeping one-half in reserve.

Although the city has access to the Mississippi River, it secures its water supply from two strata of water bearing sand, one 450 feet below the surface, the other 1400 feet. The department has 29 wells in service, all of which are not needed at one time. They are used alternately. As much as 18,000,000 gallons have been taken in 24 hours from 13 wells. From 1.0 to 1.5 million gallons of water are pumped per day from each well that is operated.

The department has approximately 380 miles of mains inside and outside of the city. There are probably 15 miles of mains outside the city. The supply mains are of sufficient carrying capacity, there being two 30-inch and one 24-inch line from the Parkway Station to supply all parts of the city. The smaller mains are 4-inch and up to 20-inch. The department does not install smaller than 6-inch mains at the present time and are replacing all 4-inch mains, which are few in number, with larger ones. All dead ends are being eliminated as fast as possible.

The department is 100 per cent metered, having over 36,000 meters in active service. In addition to this, there are approximately 300 sprinkler connections for fire protection. There are also approximately 2500 fire plugs within the city limits.

The total pumpage for the year 1926 was 5,608,455,000 gallons, or a daily average of 15,365,630.

The department furnishes all mains, all service connections, all meters and meter connections free. Meters are set in sidewalks at the curb.

Mechanical equipment

The machinery consists of (*a*) Two Worthington horizontal cross compound fly wheel pumps, manufactured in 1923. These pumps are double acting and condensing, with steam cylinders 23 by 54 inches in diameter, 36-inch stroke, and run at 45 revolutions per minute. The water plunger is 22 inches in diameter. The water pressure is 70 pounds. The daily capacity is 15,000,000 gallons each.

(*b*) Two single stage, centrifugal water turbines, directly connected through reducing gears to 650 h.p. steam turbines. The water turbines are run at 1050 revolutions per minute, maintaining a pressure of 70 pounds, and are of 15,000,000 gallons capacity each.

(*c*) Three Worthington single stage, centrifugal water driven turbines, directly connected and driven by city pressure, pumping against a water pressure of 8 pounds, and having a capacity of 9,000,000 gallons each.

(*d*) Four Casey-Hedges water tube boilers, 3500 square feet heating surface, 350 h.p., maximum pressure of 225 pounds, averaging 210,200 degrees superheat, consuming about 33 tons of bituminous coal per day.

(*e*) Four Nordberg two stage air compressors, having a capacity of 2700 cubic feet of air per minute, and with a maximum speed of 105 revolutions per minute. There are two or three compressors constantly in use during the entire twenty-four hours, according to the load. These compressors are operated at 90 to 95 per cent of their maximum capacity. It is found that these machines can be operated at a better advantage at this rate.

The electric machinery consists of two 125 h.p. Chuse poppet valve uniflow engines driving 2 General Electric 100 k.w. generators. These units are used to light the building and to operate motors which drive the forced draft to the boilers, the coal hoist, the devices of the machine shop, the crane and all auxiliary machinery in the plant. One unit is operated at the time, the other is always in reserve.

The boiler room is large and roomy, with ample light and ventilation. Each boiler is a single unit with 21-inch brick wall and is encased in steel, making it impossible for air leaks in the wall. The boilers are equipped with forced draft, each being driven by separate motor. There is a fan blower operated by a steam turbine for emergency should the electric machinery get out of order. Each boiler is equipped with Bailey meters and CO_2 Recorders. There is a surge tank, one Cochrane open heater and 3 Worthington boiler feed pumps.

The boilers are fed by four Riley underfeed stokers, from which very good results are obtained. The stokers are driven by Sturdivant engines. The boilers are equipped with four Foster superheaters which average 150 degrees of superheat. The coal is carried to the boiler room by a chain hoist to the coal hopper, which has a capacity of 500 tons. All coal is weighed before being fired and an accurate account kept. The efficiency of the boilers is above 70 per cent.

The high pressure cylinder of the Worthington cross compound condensing pumps is equipped with poppet valves, driven by cams; low pressure with Corliss valve gears. The pumps are regulated as to speed by governor control. If the pump exceeds an 18,000,000 gallon rate, the governor automatically shuts the pump down. The pumps are operated at 85 to 90 per cent of their capacity, except in emergency load, when they are operated at full capacity. The steam consumption per horse power is approximately 10 pounds. The slippage at the water end is 2 per cent.

The two general electric steam turbines are of satisfactory efficiency. Careful checking, however, shows them to be more expensive in fuel consumption per million gallons of water pumped than the cross compound. The upkeep is very small.

The Nordberg air compressors are the only compressors of the type made. The high pressure cylinder has poppet valves. The low pressure cylinder is of the uniflow and Corliss valve type. Steam consumption is from $9\frac{3}{4}$ to 10

pounds per horse power. The volumetric air efficiency is about 93 per cent. We consider them the best manufactured.

Sources of supply

There are twenty-two 12-inch wells, 450 to 500 feet deep, and seven 8-inch wells, 1400 feet deep, of which some are located on the Park Ground around the plant, some on lots facing the Parkway and others on the water department's ground in the northeast part of the city. These wells extend over a territory nearly two miles in length. The water is lifted from the wells by air and flows to a 30-inch collecting main, which increases in size to a 42-inch. The 42-inch collecting main empties into two 36-inch mains which carry the water, by gravity, into the raw water basin of the reservoir, thence to the low pressure pumps.

There are air lines running the entire distance of the wells, four 10- and two 6-inch lines leaving the plant. They cut off at different intervals, leaving a battery of six wells to be operated at one time, or as many wells can be operated at one time as is desired. It is so arranged, if lines get out of order, that we can cut out any part and keep operating just the same. All air going into the wells is measured with Jersey meters, and all water coming from the wells with Venturi meters. These readings compare with the air and water records of the meters at the Parkway Station. The amount of air consumed per minute averages approximately 275 cubic feet to 700 gallons of water raised.

When wells are at rest, water from the upper stratum stands about 50 feet from the surface; from the 1400 feet stratum, about 15 feet. The water taken from the wells before applying air shows CO_2 gas to the extent of about 135 parts per million. The air lift, aerator and filter release all but 3 or 4 per cent of the entire gas. The iron in the water is also eliminated by these means.

Aerators

Three single stage directly connected turbines are driven by water pressure from the water mains. The daily capacity is 9,000,000 gallons each. The use of the turbine is to lift the water from the raw water basin of the reservoir to the aeration plant where it passes through the riser and is distributed equally through a quadrant. It then flows through trays, of which there are 40 to each quadrant. The trays are made of cypress strips about $\frac{1}{2}$ by 1 inch, and $\frac{1}{2}$ inch

apart, and are filled with coke. The frame work supporting the trays is concrete and steel. The idea of the trays is to break the water into small particles to allow all gases not eliminated by the air lift to escape. The aerated water passes through a small baffled chamber underneath the floor and thence to the filter. The purpose of this chamber is partly for mixing, if needed.

Filters

Filters are of the rapid sand type with eight reinforced concrete units of 825 square feet each. All units have perforated pipe under drains. Beds are composed of bottom layers of graded gravel 18 inches in depth and top layers of sand 30 inches deep. The only need of the filter is to remove the iron and gas from the water, it being unnecessary ordinarily to use any chemicals for purification. However, a chlorine installation is held in readiness should occasion require its use.

The filtered water flows from the filter plant through a duct which is connected with the suction chambers of the primary pumps, and also connected with and maintaining a level flow with the filtered water basin of the reservoir. Should the consumption be greater than the supply from the filter plant, the reservoir supplies the deficiency. Should the supply from the filter plant be greater than the consumption, the excess flows to the reservoir. The capacity of the reservoir is 10,000,000 gallons.

WELL WATER RECESSIONS IN ILLINOIS[1]

By G. C. Habermeyer[2]

An artesian well 711 feet deep was drilled in Chicago[3] in 1864 at the corner of Chicago and Western Avenues and the pressure at the ground surface was about 80 feet. The owners of the well proposed to drill two 15-inch wells and secure water (20,000,000 gallons a day) at sufficient pressure to supply the city without pumping. Their expectations have never been realized, for, although many wells have been drilled into the same water-bearing stratum and other strata of which Professor Leighton has spoken, and the quantity of water pumped is increasing, the water level has receded until many wells have been abandoned on account o fthe high cost of pumping from great depths.

An important factor in the lowering of the water level is the increase in the quantity of water pumped and this will be discussed briefly for: (1) wells into porous material overlaid only by porous material, (2) wells piercing several water-bearing strata with water from all but the bottom stratum cased out, and (3) wells piercing several water-bearing strata with no water cased out.

Figure 1 shows a well into porous material into which water from the ground surface percolates freely. The line through *O* shows the the water level when not pumping and the line marked *H.G.L.*, hydraulic grade line, marks the water surface when pumping. With little lowering of water level the yield may vary nearly in proportion to the lowering. As the bottom of the stratum is approached the relative area of flow decreases and the velocity increases more rapidly, giving higher friction loss and greater lowering in proportion to the yield, until the bottom of the stratum is reached when increased lowering gives no increase in yield.

Pumping for a long time at a higher rate than the rate at which water enters the stratum will cause a continued lowering of the water

[1] Presented before the Chicago Convention, June 9, 1927.

[2] Engineer, Illinois State Water Survey, Urbana, Ill.

[3] History of the Chicago Artesian Well. Religio Philosophical Publishing Association. 1866.

level until the level is near the bottom of the stratum and then the yield will decrease.

Figure 2 shows an artesian well piercing two water-bearing strata with water from the upper stratum cased off. The line through *O* shows the height to which water rises in the well when not pumping and the line marked *H.G.L.*, hydraulic grade line, shows the elevation to which water from the lower stratum would rise while pumping.

Figure 3 shows three types of wells, *A* and *B* as in figures 1 and 2, and *C*, a well into the same water-bearing strata penetrated by *B*,

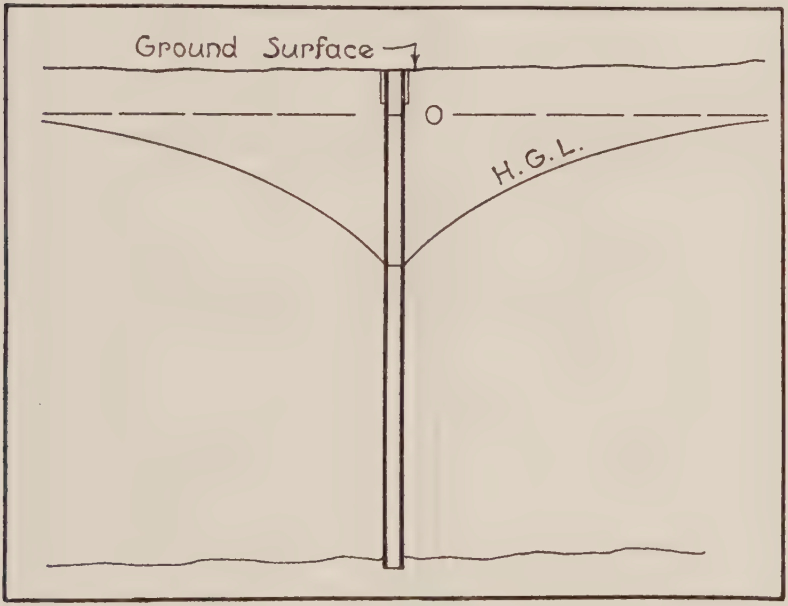

FIG. 1

but with no water cased out. A great majority of our deep wells secure water from more than one stratum as shown at *C*. With water standing at different levels in wells *A* and *B*, all water pumped from well *C* will be from the stratum from which water rises the higher, until the water level is drawn down below the depth at which it stands in either *A* or *B*. Then, with increased pumping, water will be drawn from both strata and the rate of lowering with increased pumping may be a little less or very much less than before.

Drilling and pumping from additional wells in an area may change

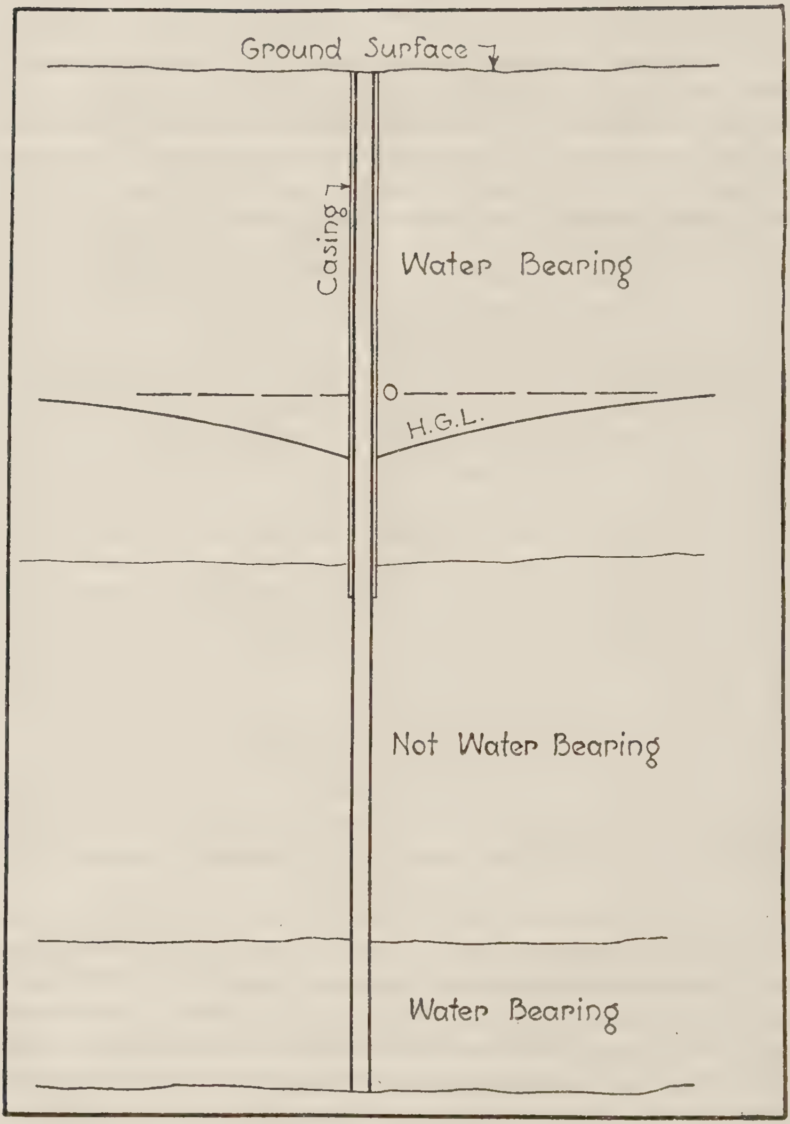
Ground Surface
Casing
Water Bearing
O
H.G.L.
Not Water Bearing
Water Bearing

FIG. 2

conditions on account of the quantity of water pumped greatly exceeding the capacity of strata which had supplied all or nearly all demands.

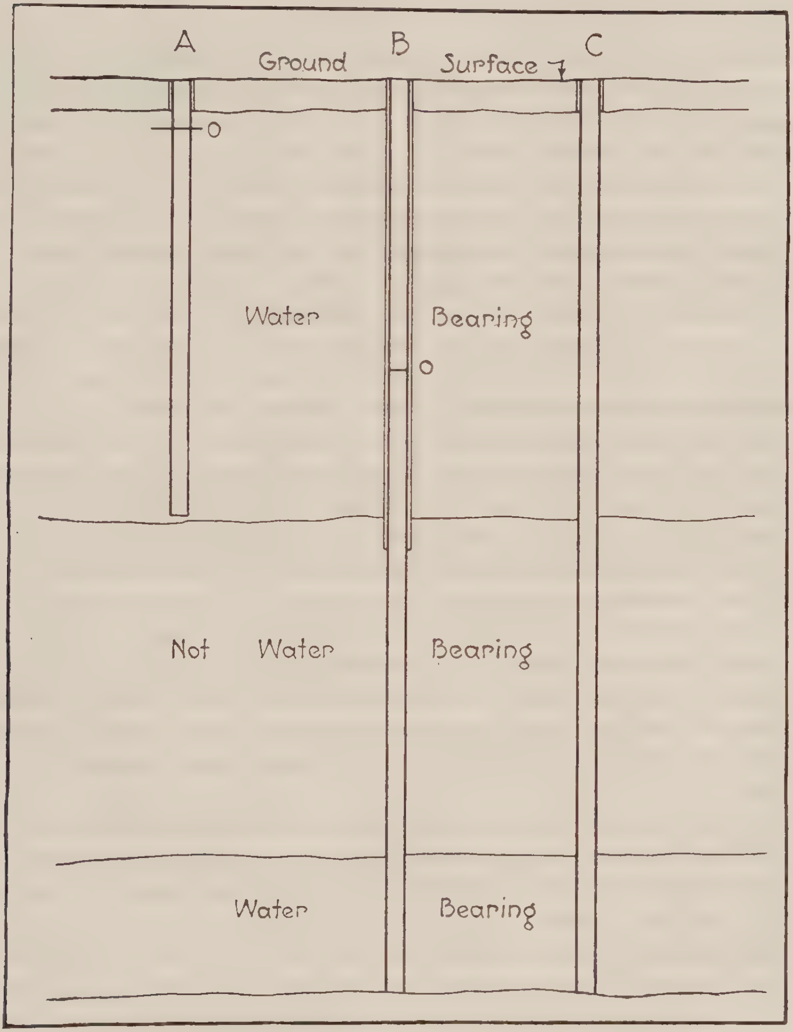

FIG. 3

The United States Geological Survey has developed a current meter to determine velocities at all depths in flowing wells, and thus determine the flow into or out of a well for each stratum.

A well in use for many years by the Village of Western Springs, a few miles west of Chicago, illustrates all three types of wells. The well was 2046 feet deep, was cased 1765 feet, to Mt. Simon sandstone, and was very large at the top, giving a well into Niagaran limestone outside of the deep casing. Pumping 110 gallons a minute from Mt. Simon sandstone lowered the water level inside the casing, 150 feet to a depth of 240 feet. Pumping large quantities from Niagaran limestone, outside the casing, lowered the water level a few feet. Shortly after the well was completed water both inside and outside the casing stood 15 feet below the ground surface and 600 gallons a minute could be pumped with a lowering not exceeding 6 feet. At least part of the casing was then out of commission, the well was of the type shown at *C*, and all water was from the upper part of the well.

Another illustration of change in conditions is at Lansing, a village southeast of Chicago near the Indiana State line, where a well was drilled to a depth of 1632 feet. When drilling in the lower part of the well the water level dropped 70 feet. Water from the upper part of the well then flowed into the well, downward, and out into lower strata. Water pumped from the well was from the upper part and had a hardness of 20 parts per million. With increasing demands, increased pumping, and draining of upper strata, the water level was lowered and part of the supply was secured from lower strata as shown by an increase in hardness of the supply to 650 parts per million.

The only reason for lowering of water levels discussed above is increase in rate of pumping. An attempt has been made to show that with increased pumping the lowering may be slight between certain limits of yield and may be great between other limits, depending upon the relative yields and water levels in various strata penetrated by a well.

A lowering of water level may be due in part to other causes. A lowering of level giving reduced pressure in a stratum may release gases from the water, causing a readjustment in dissolved mineral matters and a deposit of part of them, thus increasing friction loss and adding to the lowering if the yield is maintained. Deposits are found on equipment taken from some wells. It is claimed that blasting has restored yields of wells by removing deposits.

Growths on walls of wells and in the strata are given as a possible cause of decrease in yield or lowering of level to obtain the same yield.

Mechanical clogging of strata with fine sand or other material may add greatly to friction losses and thus to lowering of water level.

Compression of water-bearing strata is given by Oscar E. Meinzer and Herbert A. Hard as an explanation of lowering of water level.[4] A reduction of pressure in a stratum is equivalent, in some respects to increased pressure on the stratum. Increased pressure gives compression which reduces the voids in the stratum. Yields from wells in the past, greater than present yields with higher water levels than present levels, can then be explained, as part of the yields were of water in storage in the vicinity of the wells. This explains a lag in adjustment of water levels with changes in yields. Compression will also have a direct effect on the increase in friction loss.

Conditions in various states in regard to water level recessions due to the causes mentioned or possibly other causes, will be given by the persons whose names appear on the program. I shall give a few facts in regard to conditions in Illinois.

CONDITIONS IN ILLINOIS

The water levels in deep wells in northern Illinois have receded considerably. A large part of the lowering is due to increased pumping and an effort has been made to determine the quantity of water pumped from wells penetrating the lower water-bearing strata, including St. Peter sandstone and all lower strata. This is given for several areas and the Chicago suburban area is here considered as area in Illinois from Lake Michigan along the Wisconsin State line to Fox River; southward including Elgin, Aurora, and Morris; southeastward to include Kankakee; eastward to the Indiana State line; and north to the lake. Reasonably accurate data have been secured in this area by H. L. White of the State Water Survey Division. Data of municipal supplies outside of this area have been secured from Bulletin 21, issued by that survey, and from city and village officials. Few data are readily available in regard to industrial use of water from deep wells outside of Chicago and the suburban area, and this has been assumed at between 2,500,000 and 7,500,000. Quantities pumped per day for areas given are as follows:

	million gallons per day
Stock yards area in Chicago	10
City of Chicago	15
Cook County	30
Chicago and suburban area	50
State of Illinois	70 to 75

[4] United States Geological Survey, Water Supply Paper 520.

The largest yields are from wells into Cambrian sandstones. They supply about 95 per cent of the quantity given for Chicago and suburban area and probably 85 per cent of the quantity given for the state. Water levels given will be for wells into Cambrian sandstone.

The lowering of water level in the stock yards area is shown in figure 4. The curve, to 1915, is copied from State Geological Survey Bulletin 34. Water stood at the ground surface in 1889 and at a depth of 212 feet in 1914. The bulletin gives the quantity of water pumped per day in the latter year as 13,450,200 gallons in the stock yards and 30,100,000 gallons in Chicago. Since that date nearly all wells formerly in use at breweries have been abandoned and many other wells have been abandoned on account of increasing costs of

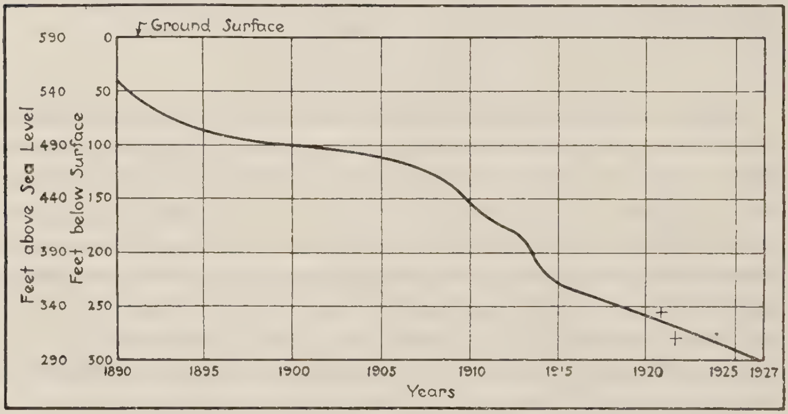

FIG. 4

pumping from greater depths and superior quality of the city supply. Some wells have been drilled and nearly all of the wells now in use are pumped almost continuously at a high rate, many yielding 1,000 gallons a minute or more. The quantity pumped in the suburbs has increased very rapidly.

Recent information in regard to levels at the stock yards is principally from Armour and Company and was secured with the assistance of G. B. Mulloy and others. The water level in one well, last month, when the pump had been idle one day, was 300 feet below the ground surface, about 290 feet above sea level. When pumping 800 gallons a minute the depth to water was close to 340 feet, as a hole was found in the suction line at that depth and other equipment in good repair in other wells discharged more water.

Within 6 miles of the stock yards, on land not more than 10 feet higher, excepting to the south and southeast where practically no deep wells are in use and we have no record, depths to water when not pumping are reported as about 300 feet, some a little more, some less. At a plant of the Corn Products Refining Company, 8 miles west and south, where land is at about the same elevation, the depth to water when pumping 2,300,000 gallons a day from a group of wells, is 340 feet.

In wells at Maywood, about 10 miles west and 5 miles north of the stock yards, in an area where the quantity of water pumped has increased rapidly, the water level was approximately 555 feet above sea level in 1907 and 375 feet above in 1927.

North and northwest of the stock yards more than 7 miles little water is pumped from deep wells. At Park Ridge, 15 miles northwest, the water level was 565 feet above sea level in 1914 and 67 feet lower, or about 500 feet above sea level in 1927.

At North Chicago, 35 miles north, wells now flow several feet above the lake level, about 590 feet above sea level.

At Rockford the water level was about 740 feet above sea level in 1885, 720 feet above in 1891, 707 feet in 1910, 697 feet in 1919, and approximately 690 feet in new wells in 1923.

At Galena, close to the northwest corner of the State, it was reported in 1886, when a well 1547 feet was drilled, that the flow was 500 gallons a minute and that water would rise to 84 feet above the ground surface, 694 feet above sea level. In 1896 water would rise to 32 feet above the ground surface. After repairing the well the pressure at the top, in 1925, with small flow through a waste valve, was 32 feet. Another well of practically the same depth, 8 inches in diameter, located 130 feet from the older well, had been completed in 1921. When pumps were not operating there was a small flow from the two wells through a blow-off valve and a pressure gauge on the pump suction registered 36 feet. When pumping from the two wells at a rate of 750 gallons a minute the pressure at the top of the wells was 8 feet, indicating that, with zero pressure at the top, a flow close to 500 gallons per minute per well could be obtained, for a short time at least.

Analysis of the causes of the recession of the water level in this state would be difficult. The majority of the wells in use pierce several water-bearing strata and have little casing, so the quantity of water pumped from each stratum is not known. Many wells more

than 1800 feet deep in the western suburbs of Chicago yield several hundred gallons a minute, of which a large part is from the upper 300 or 400 feet of the wells, as shown by low temperatures. A well at Western Springs has been given as an example.

With increased demands, wells have been drilled deeper or replaced by deeper wells into lower water-bearing strata, so that conditions are not directly comparable with conditions of ten years ago. However, practically all water pumped in the stock yards district is, and for many years has been, from wells about 1600 feet deep.

A large part of all water pumped is from Cambrian sandstone, as has been noted, but there are several water-bearing sandstones in the Cambrian system and many of the wells at one location are drilled into lower strata than are wells at other places nearby. For example, at Aurora, 35 miles west of Chicago, wells are drilled more than 1000 feet into the Cambrian system, while wells in use at the stock yards are drilled about 200 feet into this system.

About the only conclusion that can be drawn at this time seems to be that the water level lowering depends in large part directly upon the quantity of water pumped and that part of the change is due to some of the other factors which have been given as possible causes. The great lowering near Chicago may be due in part to compression of strata.

In the vicinity of Chicago, where the greatest quantity of well water is used, much of the water is now from wells drilled as deep as can be drilled without securing salty water, and the water level has receded until some wells have been abandoned, so it may be that conditions will be more uniform during the next few years and additional information can be obtained.

WATER WORKS VALUATION[1]

By Lewis E. Gettle[2]

Active regulation of water and other utilities has been in operation in Wisconsin for about twenty years. During this time certain classifications of accounts have been adopted and applied in accordance with the statutes. Yearly reports have been submitted by the utilities. From the twenty year study of plant experience, records and reports, court decisions and opinions, transfers, voluntary and otherwise, considerable knowledge has been acquired useful in regulation and in the determination of values for the issuance of securities, rate making, or of the compensation to be paid for the taking of a utility. The intent has been to maintain a healthy condition in keeping with the public welfare and the demand for service with justice both to the consumers and the owners of the utilities.

Many of the original water distribution systems and pumping stations in Wisconsin were built by contractors in the period 1880–1890 when prices of materials and the labor rate of pay were much lower than in the present so-called post-war period of readjustment. Extensions, improvements and additions were made in piece-meal fashion with the growth, development and requirements of the various cities. Following the entrance of the United States in the war construction was deferred in many cities by high prices or shortage of labor or material. Since the war construction has been resumed and appears now to be near the normal.

You are probably familiar with the fluctuations in the price of cast iron pipe. Since 1923 the price of Class B water pipe has had a downward trend, being quoted in Iron Age of May 3, 1923 at $60.20 and of September 29, 1927 at $34.20 to $37.20 per net ton f.o.b. Chicago. Common labor throughout the state has also had a downward trend except in centers of unusual activity such as Madison, Kenosha and Racine. In some cities the labor rate of pay has decreased since 1923 approximately 10 per cent. The rate of pay of skilled labor, organized,

[1] Presented before the Wisconsin Section meeting, October 14, 1927.

[2] Chairman, Wisconsin Railroad Commission, Madison, Wis.

and often at variance with common labor in leading or lagging, appears to be well maintained and advancing in some places. From the facts and the prospects it cannot be said with much assurance that we have arrived at a level of prices for water works materials and labor.

In the earliest years of regulation the commission used a reproduction cost valuation applying prices for materials and labor representing a five year average. This five year period included 1906 and 1907, years in which cast iron pipe was quoted and sold at prices higher than the other years of the period. About 1913 a ten year average for pricing replaced the five year average. With the greatly increased price of cast iron pipe and labor after January 1, 1916, and the general reduction in amount of new work done, the 10 year average reproduction cost valuation was continued for the portion of the physical property in place prior to January 1, 1916, adding thereto the actual cost of additions made subsequent to January 1, 1926. For these additions the records of the companies were available. In the calculations and estimates throughout these years the commission's engineering staff was governed somewhat by the manner in which the property had been built up, with reproduction assumed to be done in a manner corresponding to the facts found in a study of the historical development of the property. Local conditions were carefully considered and results could be predicted with some uniformity. The method and application of price bases throughout these years produced workable results with reasonable effort and generally fully covering the investment of the then existing utility.

Recent United States Supreme Court decisions and our own supreme court decision in the Waukesha Gas & Electric Company case have had an important bearing upon the rules of valuation which the railroad commission is required to apply. The decision in the Indianapolis Water Company case, while so worded as not to exclude in later cases other elements of value, seemed to indicate clearly the adoption of the policy of giving material and considerable weight to that measure of value represented by what it would cost to reproduce the existing property at present prices. If it were possible to know the Indianapolis property and to have intimate knowledge of the manner in which the estimates of reproduction cost were made and the result applied, we might the more closely understand the opinion and thought of the court and the weight which should be given to such measure of value when valuing other properties. The formulation of

a method is helpful though a statement set forth in a decision may require some time for clarification and common understanding.

CHAPTER ON VALUATION IN THE MANUAL

In chapter XXII of the manual "Water Works Practice" published in 1925 by the American Water Works Association, some of the factors and difficulties involved in valuations of water utilities are set forth clearly. In the short time at my disposal I can, of course, discuss or mention only a few items of uncertainty and those very briefly. Engineers working honestly and impartially upon the same premises may arrive at results close to each other. Ignoring the facts or methods derived from a study of the historical development of a property may allow a variation in assumptions of reproduction and corresponding differences in results. Inspection by engineers of a distribution system at a season of unusually high water, with the ground water table near the surface might result in a temporarily high reproduction cost estimate. For example, a person visiting Oconto or Marinette at certain times of the year might conclude that pipe laying in sections of these cities is extremely difficult. Likewise, very low or very high lake levels may affect the ground water table and present for several years abnormal excavating conditions. Cities by ordinances may require that pipes be laid prior to paving, yet a measure of value might be so construed as to require an estimate of cost of an equivalent dual system of piping in the terraces at the edge of a so-called permanent paving or of the cutting through of a hard pavement. New and cheaper forms of pipe are being made and sold. Which of the present forms of pipe shall be used, if the original form or type of piping is obsolete and at present unreasonably expensive to reproduce? In a reproduction cost estimate of laying pipes how much, if any, consideration should be given to the congestion in the down town district? Improvement and development of satisfactory types of machinery for the laying of mains have come within recent years. Only in a few cities have utilities had enough construction in a season to justify the ownership of a trenching machine. On large jobs today trenching machines are commonly used if soil conditions are suitable. The size of the job would determine the use of various other labor saving and cost reducing devices. Various assumptions may be made as to the order, speed and time in which a system might be built, making more or less effective the use of crews and machinery. There are many assumptions which may be made and regarded as

reasonable and in accordance with usual fact. Opportunities for differences appear numerous. Adherence or consideration given to methods employed in the development of the property may eliminate many differences. However, each case seems to present new features, new problems for solution.

The allowances usually made for construction overhead costs will be affected by the assumptions made as to time and methods of construction. The usual practice of the railroad commission of Wisconsin has been in the past to add 15 per cent to the groups, land, transmission and distribution, buildings and miscellaneous structures, plant equipment and general equipment for the construction overhead allowances. This percentage has been composed of the following items:

	per cent
Organization and legal expense	1.5
Engineering and general supervision	5
Interest during construction	5
Taxes	1.5
Omissions	2

Our engineers have drawn a marked distinction between the words "omissions" and "contingencies." When construction is originally proposed many of the later developments in such construction are unknown and cannot be foreseen. There will often be changes in plans, foundations may reveal great difficulties and increased expense and engineers generally will make a fairly liberal allowance for such contingencies. It is only after completion of the construction that it is usually possible to discover and set forth these unforeseen costs. It is quite evident that, after a plant has been completed, all of those things that were contingencies at the inception of the project have become realities and the history of the construction of the plant discloses or at least should disclose, if such history is accessible, the actual experience of the company, and these things designated as contingencies have become ascertained facts and can be so treated in the valuation. The term "omissions" is intended to cover certain used and useful items of the property which have been overlooked and omitted. Experience in the checking of inventories and the repeated listings of items indicates that an allowance of 2 per cent is quite fair for general use. In some instances the percentage has been increased or modified in accordance with the haste or manner of taking or checking the inventory.

In using an estimate of present cost of construction of a plant, less depreciation, as a fair measure of the value of the physical elements of the property the depreciation becomes an important matter for consideration. If we might have before us in advance all facts relating to the condition of the various items of inventory taken periodically throughout the life of the plant we could plot a composite curve which might be called the "experience curve" or life curve of the physical property. With obsolescence included the composite curve for certain water plants would be quite irregular and the irregularities due to obsolescence ordinarily would be expected some time after the original building of the plant. In ordinary soils in Wisconsin cast iron pipe has been found to deteriorate slowly and the corrosion, tuberculation or deposit inside may be more or less rapid depending upon the quality of the water.

In the past our engineers have used a 4 per cent sinking fund curve as a guide in lieu of the experience curve, making such modification as seemed necessary for obsolescence, from inspection, or from other knowledge of the property. A water plant may differ from other utilities in its prospect of a longer life. However, in some instances, probably rare in water utilities, the straight line basis at a particular time may in fact represent and be used to determine depreciation.

The commission must determine the value of the utility as a going concern. In cases before the commission various bases of estimating an amount to be added to a valuation of physical property have been presented. Among these are a study of the historical deficits during the development period, an estimate of the deficits which would accrue if the property in business were to be reproduced as a whole, an attempt to relate the going concern value to the amount of revenue obtained in a fixed period, and in addition various arbitrary estimates such as 10 or 15 per cent of the physical property. It seems to me that all of these bases are subject to criticism and have very serious shortcomings. Any one of them can be applied to any property in such a way as to show a going value over and above that of the physical property, even though as a matter of common sense such value cannot possibly exist. Any one of them can be applied to a utility which is thoroughly unprofitable and which has no commercial possibilities in such a way as to show a considerable going concern value over and above the physical property.

If the utility is placed in a field of unhampered return or of no real need, with no prospects of earning a profit under any schedule of

rates which could be established commercially it is not worth the cost of its physical property. Cost is not value and the property cannot and does not produce an income. If the venture has been a mistaken one and has no prospects the value simply does not exist. The going value is not an item to be superimposed upon the physical value. The going concern value is the value of the entire property as a going concern and is the only true value of such property.

THE WATER YIELD FROM SMALL WATER SHEDS IN IOWA[1]

By Floyd A. Nagler[2]

With the ever increasing pollution of our middle western streams by industrial and city sewage, it is becoming more difficult for towns situated in the river valleys to secure safe and usable water. It is only a matter of time until many Iowa municipalities will be forced to seek their water supply from the flow of small streams whose water sheds can be protected from all dangerous pollution, which is now the prevailing practice in New England.

Even though the yield of Iowa streams is less than those in the East, the runoff from exceedingly small water sheds would prove adequate for the municipal supply of most of our Iowa towns. In some parts of Iowa this flow could be conducted by gravity to the municipality concerned, but, in many parts of the state, pumping would be required. With adequate storage, the average watershed may be expected to yield close to 300,000 gallons per day per square mile. In years of minimum flow, the stream may yield only one-third of this amount.

But it is not a safe procedure to base a final estimate of the yield from a small stream upon the average behavior of its neighbors. More than all other types, small streams are deceptive.

Unfortunately, very few records have been maintained from which the yield of small midwestern streams may be accurately determined. It is impossible to estimate their behavior from that of similar water sheds located either east or west of Iowa, even though both receive the same amount of precipitation.

Stream flow observations have been maintained during portions of the past twenty-five years upon many of the larger streams of Iowa. A study of these records reveals a big difference in the average water yield per square mile of the larger streams within the state. If such differences exist in the water yield of the larger

[1] Presented before the Iowa Section meeting, September 29, 1927.

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streams, it is almost certain that even larger differences will be observed in the water yield from small catchment areas located in different parts of the state, with different vegetation cover and soil conditions. The possibility of underground leakage from small water sheds may be a large contributing factor in producing a relatively small runoff from a stream located in a region where a much larger yield is to be expected.

Beginning with April, 1922, the Mississippi River Power Company at Keokuk, Iowa, has maintained a gaging station upon a water shed of only 113 square miles drained by Sugar Creek, near Keokuk. The yield of this stream has been unusually small, indicating the possibility of subterranean flow into other stream channels. A comparison of the yield of this stream with that of another typical Iowa stream is as follows:

PERIOD	SUGAR CREEK NEAR KEOKUK	IOWA RIVER ABOVE IOWA CITY
	inches	*inches*
1922—April to December (inclusive)	2.11	3.15
1923—January to December (inclusive)	0.79	3.79
1924—March to September (inclusive)	4.42	7.45
Total	7.32	14.39

It is probable that Sugar Creek received a rainfall equal to or more than the average rainfall upon the Iowa River basin, and it is surprising to note that its runoff during this period is only one-half that obtained from the Iowa River.

There is possibility of so great a difference between the yield from small streams that no water supply project contemplating such a source should be undertaken without making some measurements over a short period of time to determine the relative yield of the stream in question as compared with that to be expected from the average in that section of the state.

Realizing the scarcity of the existing data upon the yield from small water sheds in the middle west, the State University of Iowa has maintained continuous observations upon the yield from the water shed of Ralston Creek draining only three square miles of land devoted to agricultural purposes near Iowa City. The writer knows of no other continuous measurements which have been made upon

TABLE 1

Yield of water from Ralston Creek compared with run off of Iowa River at Iowa City

YEAR	MONTH	RALSTON CREEK AT IOWA CITY, 3 SQUARE MILES		IOWA RIVER AT IOWA CITY 3140 SQUARE MILES RUN OFF
		Precipitation	Run off	
		inches	*inches*	*inches*
1924	January			0.06
	February			0.30
	March			1.19
	April			0.82
	May			0.36
	June			1.37
	July			1.83
	August			1.43
	September	2.40	0.15	0.45
	October	1.57	0.09	0.30
	November	0.85	0.04	0.21
	December	1.61	0.18	0.21
Total........................		6.43	0.46	8.53
1925	January	0.28	0.05	0.16
	February	1.23	0.68	0.19
	March	0.95	0.47	0.31
	April	2.88	0.19	0.21
	May	0.79	0.04	0.12
	June	4.75	0.19	0.23
	July	3.23	0.01	0.15
	August	3.15	0.06	0.09
	September	5.52	0.13	0.07
	October	3.70	0.14	0.53
	November	0.83	0.12	0.22
	December	1.43	0.29	0.18
Total........................		28.74	2.36	2.45
1926	January	0.82	0.78	0.24
	February	1.65	0.72	0.52
	March	0.82	0.25	0.53
	April	1.79	0.67	0.36
	May	1.82	0.12	0.17
	June	5.67	0.49	0.26
	July	3.50	0.07	0.14
	August	4.64	0.16	0.23
	September	9.70	1.87	1.86
	October	1.07	0.55	0.94
	November	3.16	0.93	0.54
	December	0.90	0.42	0.40
Total........................		35.54	7.03	6.19

TABLE 1—*Continued*

YEAR	MONTH	RALSTON CREEK AT IOWA CITY, 3 SQUARE MILES		IOWA RIVER AT IOWA CITY 3140 SQUARE MILES RUN OFF
		Precipitation	Run off	
		inches	*inches*	*inches*
1927	January	0.24	0.15	0.28
	February	1.32	0.86	0.64
	March	3.37	1.28	0.60
	April	4.55	1.60	1.04
	May	6.54	2.22	1.48
	June	5.59	3.50	0.78
	July	1.70	0.14	0.24
	August	1.69	0.04	0.21
Total		25.00	9.79	5.27

the yield of such a small Iowa stream. Some larger streams have been under observation for some time by the engineers of the United States Geological Survey. Those draining an area less than 500 square miles are as follows:

STREAM	STATION	DRAINAGE AREA	PERIOD OF RECORD
		square miles	
Sugar Creek	Keokuk	113	April, 1922, to date
Squaw Creek	Ames	210	May, 1919, to 1924
Maquoketa River	Manchester	226	June, 1903, to July, 1903
Skunk River	Ames	320	July, 1920, to date
West Nodaway River	Villisca	350	May, 1918, to 1925

All of these streams are *rivers* compared with Ralston Creek upon which studies are being made by the staff of the Hydraulic Laboratory at the University. Yet, with complete storage, Ralston Creek drains an area large enough to furnish an average of 1,000,000 gallons per day in an average year.

The runoff from Ralston Creek is being accurately measured by means of a triangular control weir and an automatic water stage recorder. In addition to the runoff record, the precipitation upon the water shed is being measured by seven rain gages distributed over the basin. One of these rain gages is a recording rain gage, so that

records are being obtained of rainfall intensity as well as total amount. Observations of the level of the ground water are made every ten days in eight wells distributed over the water shed. These records have been maintained since September, 1924, and the monthly results showing the runoff and precipitation are given in table 1.

A comparison of the yield of this small water shed with that of the Iowa River, the yield from which is quite typical of the average from Iowa streams, indicates that the *total* yield may be quite similar. However, during wet periods the yield from the small water shed is considerably in excess of that which may be realized from the larger stream and during dry seasons the small water shed has a lower flow per square mile than that existing in the larger river.

The Ralston Creek observations are not only furnishing reliable data with respect to the water yield from a typical small midwestern drainage area, but valuable information is being obtained as to the intensity and distribution of intensity of midwestern storms, the magnitude and time of concentration of flood runoff, the reliability of readings of adjacent rain gages, the influence of vegetation upon stream yield, the rate of infiltration of rain water into soils, and the influence of ground water upon stream flow.

COUNCIL BLUFFS' RECENT WATER WORKS IMPROVEMENTS[1]

By Arthur L. Mullergren[2]

The city of Council Bluffs, Iowa, has just completed a new high service pumping station and improvements to its low service station as a part of its program of development for the future.

The Board of Trustees found that their existing pumping facilities were becoming inadequate for the growing demands and that the operating costs were steadily increasing. They determined that before any improvements were undertaken it would be advisable to have a thorough survey made to determine the most feasible scheme of development and most economical types of equipment for the present as well as future conditions.

The author was retained as consulting engineer to make a thorough survey and study of their water works system, make recommendations as to the proper method of procedure and determine the kind of improvements that should be made to fit in with the future requirements. The recently completed high service station and the improvements to the low service station are, in part, the result of the survey and recommendations.

DESCRIPTION OF PRESENT SUPPLY

The water supply is obtained from the Missouri River by means of an electrically operated low service pumping station located on the banks of this river. The low service equipment consists of one 12 and one 11 million gallon per day 32-foot head single stage centrifugal pump, each direct connected to a 100 h.p. induction motor, and one 8 million gallon per day centrifugal pump direct connected to a Sterling gasoline engine. The gasoline unit is used as reserve equipment or for emergency service. These pumps discharge into seven large settling basins located immediately adjacent to the pumping station, and known as the Dodge Park site. After

[1] Presented before the Iowa Section meeting, September 30, 1927.

[2] Consulting Engineer, Kansas City, Mo.

passing through these basins the water flows through a 24 inch line to three large settling basins located at the Broadway high service station site. The distance between the two sets of basins is approximately 3500 feet. To provide a sufficient flow of water between the two sets of basins, an 8 million gallon electrically operated booster pump is used. Water is supplied to the distribution system by the Broadway high service station.

No filters are used, but the city has been able to furnish a very satisfactory quality of water owing to the large amount of sedimentation basin capacity. The water is treated with lime and alum at the Dodge Park basins. Liquid chlorine is supplied for sterilization at the suction of the high service pumps.

Owing to the topography of the city, booster pumps are required to serve two districts which have elevations considerably higher than the main part of the city. Water is pumped through the distribution system into a large concrete storage reservoir which floats on the system and its elevation gives approximately 65 pounds pressure to the main part of the city. One of the district booster stations is located at this concrete storage reservoir and takes the water directly from the reservoir and pumps into the district supplied by means of duplicate 300 gallons per minute electrically operated centrifugal pumps. The other booster station takes its water directly from the main distribution system and pumps into its high service district. Each district has an elevated steel storage tank of sufficient elevation to give domestic pressure to its district. These two districts are some distance apart, but the elevated tanks have their overflows set at the same elevation so that it is possible to tie the two together and supply both from either pumping station. This is another one of the recommended improvements.

Before the new motor driven high service station was installed, the high service pumping equipment consisted of two 8 million gallon triple expansion pumping engines and three 250 h.p. Scotch Marine type boilers designed for 150 pounds pressure. However, it was found that it was impossible to secure more than 6½ million gallons per day from one of the pumping engines owing to the condition of the equipment, and the plant was practically dependent on one unit during the peak season, as the peak requirements were in excess of this amount. The Board of Trustees were confronted with the problem of either installing an additional pumping engine for the same steam conditions or else install a new pumping plant in order to use the

latest types of pumping equipment. The maintenance and repair items on the pumping units and boilers were increasing yearly and the overall efficiency of the plant was low due to the poor steam conditions, type of boiler settings and general arrangement of piping and installation. In view of the fact that the entire water supply of the city was dependent upon this station, it was impossible to dismantle same or completely rehabilitate it until the new pumping equipment was installed.

REVIEW OF NECESSARY IMPROVEMENTS

A very thorough study was made of the pumping requirements and conditions to determine the types of equipment that would be most economical and suitable for Council Bluffs. The triple expansion pumping unit was eliminated from consideration due to its higher annual costs over the steam turbine type. Either type of equipment would necessitate the installation of additional boiler facilities in order to secure the advantages of better steam conditions and also to secure a gain in efficiency of boiler operation over the existing boilers.

Complete analyses were made of the cost of installing and operating three types of pumping equipment, as follows: steam turbine driven pumping units, Diesel oil engine pumping units, and electric motor driven pumping units.

It would have been possible to install in the old pump room one steam turbine driven pumping unit of 8 million gallons daily capacity, and, at a later date, one of the old triple expansion pumping units could be removed and a second turbine driven unit installed in its place. It was found that the boiler room would have to be remodeled and one of the existing boilers removed in order to provide space and height for suitable capacity higher pressure boilers. However, this arrangement would have necessitated operating the old triple expansion units at one steam pressure with its boilers and the new turbine units at another steam pressure with its boilers. This would have caused some complication in the piping arrangement until such time as the second turbine driven unit was installed with its boiler so as to provide duplicate equipment throughout. The building in which the old equipment was housed would have had to be rebuilt, as it was not fireproof and not of the design desired for modern pumping equipment.

For a Diesel engine installation a complete new building would have been necessary owing to the height and additional space required. It

was found that a complete new motor driven pumping station could be constructed at a smaller cost than endeavoring to install the steam equipment in the old building in the manner outlined above. In view of the fact that the low service station and low service booster pump were already electrically equipped and operated and electric current purchased from the local power company for these stations, and the rates offered by the power company were on a sliding scale, a great advantage could be secured from the lower rates offered by the increased use with additional motor driven pumping equipment. Owing to the fact that the low service station and the low service booster pump were located at different sites and separated from the high service station and the pumping head was very small, purchased electric power for these two stations showed a decided advantage by reason of the fact that extra attendants would be unnecessary.

In working out a comparative set-up of operating charges for the different types of plants considered, it was necessary to take into consideration both low service stations. The best set-up for a steam turbine pumping plant would be the installation of high service steam turbine pumping units in duplicate of 8 million gallon daily capacity each, with alternating current generators installed on an extended shaft on each unit of sufficient capacity to operate the low service pumps and the low service booster pump. These pumps could be operated simultaneously with the high service pumps, as the high service storage reservoirs and the low service sedimentation basins were of such capacity that very flexible operation could be secured. The annual operating charges, including fixed charges of 11 per cent, were found to be $52,800 for an installation of one turbine unit and its necessary boiler equipment in the present building and remodeling same. For a complete new turbine plant in a new building, duplicate units throughout, the annual operating charges were found to be $63,600.

The Diesel engine pumping equipment installed in a complete new building with duplicate Diesel oil engine generating units of sufficient capacity to operate the high service pumps and all low service stations and the installation of duplicate motor driven 8 million gallon per day high service pumps, carried an annual charge of $64,000. The fixed charges for this unit were determined to be 12 per cent of the investment and considered depreciation at 6 per cent in addition to maintenance and repairs at 2 per cent.

For purchasing all of their electric power requirements the following rates were offered by the power company:

Primary or demand charge:

$1.25 per month connected horse power first 200 h.p.
1.05 per month connected horse power next 200 h.p.
0.80 per month connected horse power next 200 h.p.
0.65 per month connected horse power next 200 h.p.
0.50 per month connected horse power all in excess

Plus energy charge:

1½ cents per kilowatt hour for the first 10,000 kilowatt hours
1 cent per kilowatt hour for the next 15,000 kilowatt hours
¾ cent per kilowatt hour for all in excess

The above subject to a coal clause.

The high service installation would require 500 h.p. motors which would be of the synchronous type. Based on their previous average pumping records, it was found that the new high service station, the low service station and the booster station would use approximately 2,250,000 k.w.hrs. per year, with a connected motor load of 650 h.p. With this annual pumpage the annual rate throughout the year was determined to be 1.19 cents per k.w. hour. The annual charges for this installation with a complete new motor driven high service pumping station with duplicate 8 million gallons per day units and a Diesel oil engine generating unit for standby service of sufficient capacity to operate the high service, low service and booster stations would be $61,620, including all fixed charges. This annual charge would have been around $53,000 in the event only one motor driven unit was installed in the old building and the present steam plant was used as a standby, but for the reason stated hereinbefore, it was deemed inadvisable to consider this arrangement.

Coal costs were computed at $5.00 per ton delivered at the boiler plant for the steam installation, fuel oil at 6 cents per gallon delivered for the oil engine installation and electric current at the rates hereinbefore set out for the purchasing of power.

CHOICE OF ELECTRIC DRIVE

By comparison of the above annual charges of the three types of plants for a complete new pumping station in each case, it can be seen that the electric driven pumping station, with purchased current, was most economical and provided as reliable a service as the other two

types of plants. The reliability of service was assured by requiring the power company to install duplicate transmission lines to the high service station. The Diesel standby generating unit will afford further reliability as in event both power lines are down or trouble is encountered at the power station, the Diesel generating unit can be placed in operation within ten minutes and all three pumping stations immediately placed in operation. Duplicate underground cables will connect the high service and low service stations so as to afford reliability for the low service stations. Further reliability is secured at the low service station by the installation of a Sterling gas engine centrifugal pumping unit, making this low service station absolutely self contained.

With the present water storage capacity for both the high service and low service stations, it is possible to operate all pumping units at their full rated capacities and efficiencies and the hours of operation can be regulated accordingly.

The sizes of the units selected are such that only one unit will be required at any time to take care of the immediate requirements of the city. This condition should prevail for several years to come. It is to be noted in the layout of the high service plant that a duplicate of the initial installation can be made by an extension to the building without destroying any of the investment already made. Furthermore, in the event it becomes necessary for the power company to increase its present rates and the city finds that it can produce its power more economically, a duplicate Diesel oil engine can be installed by extending the present building and all power required for pumping can be generated at this station. The annual costs will not exceed the present annual costs. Duplicate Diesel oil engines would provide the reliability required and further reliability could be secured by using the power company for standby service only.

The operating and maintenance costs, without considering the investment or fixed charges, of the original steam high service station and the two motor driven low service stations, was around $60,000 for the past year. The maintenance charges were steadily mounting and, in the course of a year or two, the total operating costs of the old equipment would probably exceed $65,000 annually. In addition the equipment was not adequate for the city's requirements and did not provide sufficient reserve capacity. The new installation, in addition to affording absolutely reliable and adequate service, will have no greater annual costs, including the interest on the investment

made and all other fixed charges, than the direct operating costs of the old installation.

FUTURE IMPROVEMENTS

It is also proposed to install at a later date a concrete intake in the river provided with traveling screens. There will also be installed at some future date a new low service station at the Dodge Park site, so arranged that the pumps are set below the normal river level and operated with a positive suction head.

Other improvements recommended and which will be made by the city as rapidly as funds permit consist of reinforcing the distribution system so as to reduce the operating pressure at the station and afford better pressure at different points.

All of the above outlined improvements have been made from the funds derived from operations and no bond issue was necessary.

DEVELOPMENTS IN CAST IRON PIPE[1]

By H. Y. Carson[2]

The most striking development in the cast iron pipe industry has been the manufacture and introduction of centrifugally cast pipe. This material is of closer grain, greater strength and lighter weight than the standard adopted by the American Water Works Association. The cast iron pipe business is subject to very keen competition and this is accentuated by the heavy fluctuations in the production of cast iron pipe because of the alternation of bad and good times. As the cost of labor and materials entering into the price of cast iron pipe are ever on the increase, the manufacturer must install new or additional labor saving devices as well as ways and means of using to better advantage the available raw materials.

Making pipe by the centrifugal method gives promise of some material reductions in the cost of pipe, but sufficient time probably has not elapsed to determine this point.

The evolution of casting pipe first into 2- or 3-foot lengths and on up to 6, 9, 12 and 16 feet would, had we the space, make a story involving interesting details concerning the foundry business. The idea of casting pipe into 20-foot or even longer lengths might well have continued to command the attention of engineers had not the new art of bronze-welding standard lengths into 24- and 32-foot and longer laying lengths been developed.

It is natural that water distribution engineers should watch these developments with keen interest. It is significant of real progress also that the pipe manufacturer is studying with just as keen interest the field problems of those who use pipe. Coöperation is the "open sesame" to the successful future.

ELIMINATING JOINTS

Of course, the reason water works and distribution engineers have been concerning themselves about longer length pipe is to prevent

[1] Presented before the Chicago Convention, June 10, 1927.

[2] Consulting Research Engineer, National Cast Iron Pipe Company, Birmingham, Ala.

losses. The volume of water unaccounted for has in the past few years been made to dwindle from astounding figures like 50 to 25, 15 or 10 per cent. The figures are still too high.

In the built up metropolitan districts, "unaccounted" losses may not be the chief concern, but rather the damage from leaking water to property adjacent to mains. The question of how long to make the sections of pipe between field-made joints involves several considerations, such as the ability of the pipe itself to yield under external loads, the character of the joints with reference to their practicability for expansion, contraction, traffic vibration and ability to grow tighter instead of looser with age. Some of these considerations have been logically answered, but others are yet to be solved. Cast iron of high strength and having ability to yield without breaking is being studied. We can look forward to much progress in the metallurgy of cast iron.

BRONZE-WELDING

The making of long sections of bell and spigot pipe by welding together ordinary standard lengths is now an established practice, but since the technical phases of this work have been printed elsewhere[3] repetition is unnecessary.

In the repairing of breaks or cracks in cast iron, there has been at least one good method developed and the writer believes it is worth transmitting to distribution engineers. The method alluded to involves regular oxy-acetylene procedure and has come to be known as the "back stepping" method of bronze-welding.

To carry out the work of bronze-welding a cracked or broken cast iron pipe, the operator must bear in mind that two forms of breaks may call for different treatment. One form of break which no doubt is the most common is a cracked bell or a cracked spigot. Such a crack may extend longitudinally 6 to 24 inches or more. Another form of break may be in the barrel of the pipe, either running parallel to the axis of the pipe or following an irregular line partly around the circumference of the pipe.

Except in one particular, the rules for bronze-welding a crack in cast iron are identically the same[3] as to (1) preparation of the welded surfaces, (2) thickness and width of bronze, with dimensions based on thickness of the iron, as shown in table 1, (3) speed of welding, and

[3] Acetylene Journal, March, 1926, "Bronze-Welding Cast Iron Pipe," also, Gas Age-Record, May 7, 1927, p. 659.

other features of regular bronze-welding. In the procedure for bronze-welding a crack in the main body of a cast iron pipe, the operator begins his work at one of the terminals or ending places of the crack and lays the bronze on 1 inch of the cracked surface and from the proceeding 2 inches beyond the end of the crack, thereby overlapping the sound or uncracked portion of the pipe, so as to amply "cover up" the invisible portion which might otherwise extend itself out of bounds. The welder must be cautioned against heating and

TABLE 1

Practical bronze-welding data

NOMINAL DIAMETER OF PIPE	THICKNESS CLASS "A" PIPE	IDEAL WIDTH	IDEAL THICKNESS	IDEAL SPEED OR TIME OF WELDING*
inches	*inches*	*inches*	*inches*	*minutes*
2	0.25	0.40	0.61	4.0
3	0.39	0.60	0.082	6.5
4	0.42	0.65	0.091	8.0
6	0.44	0.67	0.094	11.0
8	0.46	0.71	0.098	15.0
10	0.50	0.75	0.105	18.0
12	0.54	0.82	0.114	21.0
14	0.57	0.86	0.121	24.0
16	0.60	0.91	0.127	28.5
18	0.64	0.97	0.135	31.0
20	0.67	1.03	0.142	34.0
24	0.76	1.15	0.161	41.0
30	0.88	1.35	0.186	50.0
36	0.99	1.55	0.211	60.0
42	1.10	1.67	0.232	75.0
48	1.26	1.92	0.270	85.0

* This amounts to linear inches of welding per minute.

thereby expanding the main section of the crack, but he can do this after first closing off the end of the crack with bronze. The next step is to back away from the first section of bronze a distance of 3 inches and lay additional Tobin bronze on the crack up to and joining the first lot of bronze. The third (and each other following successive step) is simply to repeat this so-called "back-stepping," until the entire crack is covered with the proper amount of bronze, as indicated in table 1. A 100 per cent weld is thereby produced, which means the attainment of strength equal to the original strength

of metal before the crack or break occurred in the pipe. When a crack at the spigot or bell end of a pipe is to be bronze-welded, the operation is even simpler, since it becomes only necessary to start welding 2 inches beyond the terminal end of the crack in the barrel of the pipe and proceeding to the open end of the crack at either the face of the bell or the spigot, as the case may be.

There are cases where it may be desired to make what is called a "Shear-Vee" weld.[4] This is done with the Tobin bronze coming even with the outer surface or periphery of the pipe. The operator should

FIG. 1. LARGE DIAMETER, CEMENT-LINED, CAST-IRON PIPE TAPPED FOR THE ADDITION OF TEES

prepare such a job very carefully by cutting or grooving out with sharp chisels or grinding a small channel in the cast iron. The crack, of course, should be exactly in the center of this grooved channel and the dimensions of the cut-out portion may be determined by following the rules laid down in table 1. The operator should use a small V-shaped cut. If, for instance, the thickness of the

[4] "An Improved Joint Design for Bronze-Welded Cast Iron Pipe," by T. W. Greene and F. G. Outcault, Gas Age-Record, November 12, 1927, p. 741.

cast iron is 1 inch, the depth of the channel will be 0.21 inch and the width 1.55 inches. After the proper channel is cut for the

Fig. 2. Two Large Pieces of Pipe Welded Together With Welded Tees

Fig. 3. Assembled Manifold

reception of the bronze, the procedure of carrying the work to a conclusion is identically the same as has already been described.

Figures 1, 2 and 3 illustrate an interesting combination of two important developments in the cast iron pipe industry, a combination of cement lining and bronze-welding.

The photographs show three successive steps in the manufacture of cement lined manifolds for a filtration plant. Figure 1 shows a

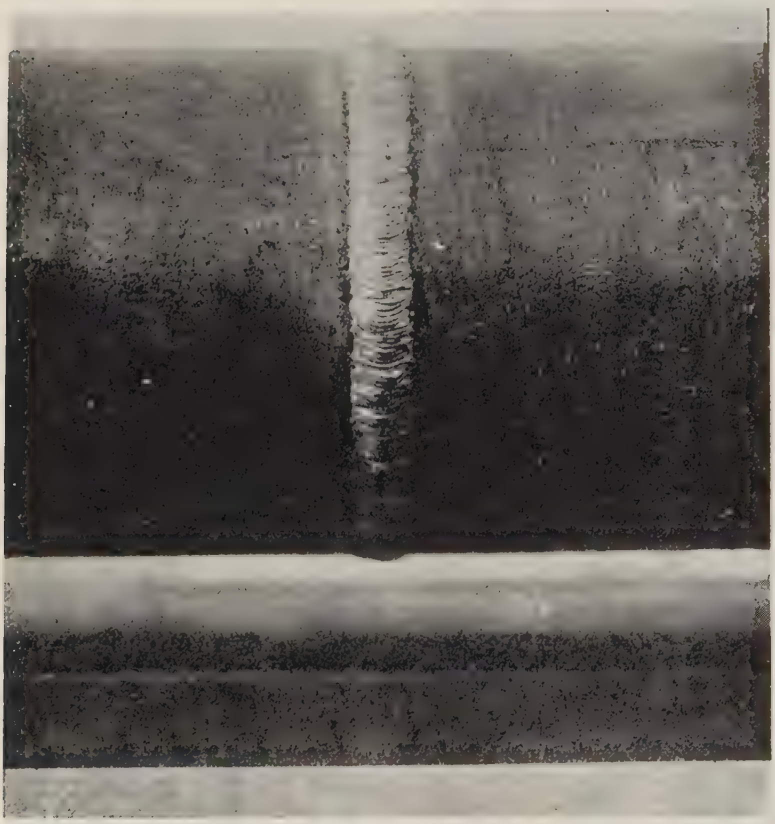

FIG. 4. A TYPICAL JOINT BRONZE WELDED ON 12-INCH CAST IRON PIPE

large diameter pipe cement lined and tapped, in preparation for the bronze-welding. Figure 2 shows two pieces of large diameter pipe welded together and the small tees bronze-welded over the holes tapped in the big pipe. The manifold completely assembled ready for installation is shown in figure 3.

The art of bronze-welding cast iron has many useful applications

in the use of pipe. It not only simplifies and reduces the cost of complicated fittings, such as the manifold illustrated, but it is being more used for repair work in general.

CEMENT LINED CAST IRON PIPE

For special services, as in the conveying of waters the chemical contents of which tend to produce tuberculation of the pipe, or where some unusual conditions of corrosion or internal friction exist, pipe foundries are equipped to furnish cast iron pipe lined centrifugally with cement mortar approximately $\frac{3}{32}$ to $\frac{3}{16}$ inch in thickness.

Tests show the cement lining to have not only the advantage of preventing tuberculation, but the flow of water through cement lined cast iron pipe is considerably greater than that through new tar dipped cast iron pipe. Depending upon the size of pipe, the velocity of water and corrosiveness or other chemical characteristics, it can be safely stated that the cement lining for pipe generally brings about an increase from 10 to 50 per cent of flow capacity with the same unit drop in pressure. In most instances, cement lined mains give assurance of being far more dependable than tar dipped pipe and for these reasons the writer believes that cement lined cast iron pipe will become standard even where the water has no highly tuberculating effect.

Apparently, the money spent on investigations of underground distribution systems as well as many other lines of endeavor is yielding some acceptable solutions to important distribution problems, increasing the durability and service value of cast iron pipe, and, above all, preventing large economic losses which otherwise might accrue to posterity who must use the thousands of miles of arteries designed to transport life supporting materials, such as water and gas.

THE TREATMENT OF WATER FOR LOCOMOTIVES[1]

By Wm. Barr[2] and Robert W. Savidge[3]

The treatment of water for locomotives consists of clarification to remove suspended matter and softening to remove the scale-forming salts. For the purposes of this discussion, treatment may be restricted to softening only. The clarification of stream water is an important problem in railway water supply, but the problems involved in sedimentation and filtration are a separate topic and will not be considered here, except as they are a part of the softening process.

On railways, methods for water treatment may be classified as partial and complete. Partial treatment is usually accomplished by the use of boiler compounds or soda ash. Of boiler compounds there are many. A new one appears almost every week. Most of them have some virtue and are usually applied in the tender of the locomotive and there react with the water when they have slowly dissolved.

BOILER COMPOUNDS

A typical boiler compound contains some alkali, usually some kind of tannin extract, and frequently silicate of soda which is also strongly caustic. The alkalies neutralize the half bound carbon dioxide and partially or wholly precipitate the bicarbonates of calcium and magnesium. Soda ash, usually present, precipitates part of the sulfates of calcium and magnesium, and some of the other ingredients may precipitate some of the scale-forming material as a sludge, so that it will not form a hard scale. The tannin extract is presumed to absorb some of the free oxygen, but the amount is usually not sufficient to have any very pronounced effect.

Some boiler compounds contain a great variety of substances which have no very direct relation to the actual softening process.

[1]Presented before the Boiler Feed Water Sessions, Chicago Convention, June 8, 1927.

[2]Consulting Chemist, Union Pacific System, Omaha, Neb.

[3]Chemist, Union Pacific System, Omaha, Neb.

Through some fancied idea of the manufacturer, or in order to produce a compound which will differ in appearance from the others, and on which a selling talk can be made with a somewhat obscure background of facts, these substances, which have no value whatever, are often added. Some compounds, having a certain value, are somewhat misused in boiler compounds, as, for example, sodium silicate which often appears in diluted and colored form and occasionally in full strength, and the buyer is told that the material contains no free alkali. It is a well known chemical fact that sodium silicate has a very strong caustic alkalinity and any such argument is false.

If used in boilers with full knowledge of the material, a certain benefit may be derived, although it is hardly to be recommended as an extremely efficient boiler compound. One of these sodium silicate compounds, with many claims attached to it, was thoroughly tested by the U. S. Railroad Administration a few years ago, and its use was condemned, not because it was utterly worthless, but because it did not fulfill the claims made for it.

In using boiler compounds it should be understood that it is only a partial treatment and that results are not to be expected that will be comparable to the use of a water with practically all of the incrustants removed.

A number of railroads make boiler compound for their own use and thus effect a considerable saving. This, however, should not be done except by someone who has made a study of such materials and who will carefully follow the application so as to secure the most satisfactory results.

USE OF SODA ASH

Another method of partial treatment which has been in use in recent years is by the addition of soda ash or some compound containing soda ash, in the wayside water tank. A certain amount of the hardness may be precipitated here, although in cold waters there is not much precipitate formed until the water enters the boiler. It is readily seen that in such cases all of the precipitate forms in the boiler and an excessive use of the blow-off will be required to handle such treatment. It is the judgment of the writers that is is not feasible to try to make water softeners out of locomotive boilers. While some relief can be obtained by internal treatment, such, for example, as adding a sufficient amount of soda ash to convert all of the sulfate hardness into carbonates, it cannot be expected to accomplish the

results of complete treatment, nor can the water be as successfully handled when the engineer is required to effect the sludge removal from the engine rather than from an outside tank. The use of anti-foaming compound is sometimes practiced with such treatment in order to reduce the foaming introduced by an excessive amount of sludge. Considering the excessive use of the blow-off, with its waste of fuel, and the use of an additional compound to reduce foaming, together with the fact that scale formation has not been completely eliminated, it must be concluded that this method is simply a palliative measure and should be used only with a full understanding of this fact.

The complete treatment of water may be obtained by the use of water softeners, either by the lime-soda, zeolite or barium methods. The use of barium treatment has never been very extensive. This is due to the high cost of barium salts combined with the fact that barium is decidedly toxic. There is always a chance that, unless treatment has been complete and clarification perfect, this may be a source of trouble. Barium treatment is only advantageous when there is a large amount of incrusting sulfates which barium carbonate will remove without leaving an equivalent amount of sodium sulfate in the water.

ZEOLITE TREATMENT

Zeolite treatment has been largely confined to laundries and the textile industries. It consists of passing the water through a bed of sodium zeolite, which exchanges its sodium for the calcium and magnesium content of the water. As a softening process, it is very effective and can be made to produce water of practically no hardness. In order to have effective zeolite treatment the water must not be turbid or contain excessive amounts of iron compounds. It is therefore necessary to filter such water before passing through the softener. Zeolite treatment was tried a number of years ago on one of the railroads, but was abandoned. It is now in use to a limited extent on one railroad, but has not been in operation for a long enough period of time to judge results.

There are certain theoretical considerations which must be taken into account in the application of this process to railroad service. In general, the action of a zeolite softener is to exchange the bicarbonates of calcium and magnesium, and the sulfates of calcium and magnesium, for the corresponding sodium salts. There is, therefore,

no appreciable reduction in the total solids of the treated water. Since the majority of hard waters carry a considerable amount of bicarbonate hardness, most zeolite treated waters have a large excess of sodium bicarbonate.

The greater the amount of sodium salts in solution, the greater will be the tendency to foam, and sodium bicarbonate especially aggravates this trouble. The zeolite method has the advantage of being very convenient to operate, but in most cases the operating cost exceeds that of the lime-soda process. It is also very important in operating such a softener for boiler purposes, that the calcium and magnesium chloride brine, which is a product of regeneration of the zeolite with salt solution, be thoroughly washed out of the softener before it is again put in operation. There may be certain places in railway service where the zeolite softener can be successfully and advantageously used, but this field is extremely limited. It is the general opinion of railroad water engineers that some form of the lime-soda water softener is better adapted to general railroad use.

LIME-SODA SOFTENER

The lime-soda water softener has been used in railroad service for more than twenty-five years. However, the design and efficiency of this type of softener has been greatly improved as a result of careful study of the operation of many machines during this period of time. The writers are still operating some softeners of this type that were built in 1903, although they have been changed in no way, they are giving reasonably good results.

The theory of operation of the lime-soda softener is quite generally understood. The bicarbonates of calcium and magnesium are broken up and precipitated by lime. The sulfates of calcium and magnesium are converted into carbonates by the addition of soda ash, and the magnesium carbonate finally converted to magnesium hydrate by more lime. With sufficient agitation and reaction time, and proper filtration, clear soft water is obtained. The bicarbonates of calcium and magnesium are reduced to a minimum of about one and one-half grains per gallon and sulfates of calcium and magnesium are converted to sodium sulfate. The ideal result cannot be uniformly obtained by the use of lime and soda alone.

The chemical reactions involved in the softening operation follow the law of mass action and are very definitely accelerated by heat and retarded by cold. In the winter months it is extremely difficult to re-

duce the hardness of a refractory water as low as desired for boiler use without the addition of some reagent to drive the reaction further toward completion.

Use of sodium aluminate

The use of sodium aluminate has recently been introduced for this purpose and with marked success. Added after the other chemicals have had a chance to react, it reacts quickly with the residual calcium and magnesium salts, producing a good floc which assists in carrying down the precipitate already formed, and effects a completeness of reaction which has not been possible in cold solutions with the ordinary treatment previously applied. In order to obtain complete precipitation in any case it is necessary to add a reasonable excess of the reagents that bring about the softening process.

On the other hand, the operation of locomotives requires that too great an excess alkalinity in the water should be avoided, as this, combined with precipitation which accumulates in the boiler, may induce foaming. However, it is important that water be treated completely because incomplete treatment gives rise to after precipitation which causes trouble in pipe lines and in the boiler. From this it is seen that in railway water softening, it is necessary to study this reaction carefully and learn just how far the softening should be carried to effect the best results.

Some municipal softening plants introduce carbon dioxide into the treated water to prevent after precipitation and to improve the taste, but this has never been shown to be profitable in handling water for boiler feed purposes.

Methods of applying chemicals

A great deal of study has been given to the methods of applying the chemicals to the water, as well as the mechanical handling of the water during the entire softening process, and this has been proved to be just as important as the use of the correct amount of chemicals themselves.

The ordinary softening practice in a ground operated machine is to mix the lime and soda ash with water in a chemical mixing tank. This is then pumped, either after dilution with soft water, or as it exists in the mixing tank, to the top of the softener, where it is mixed with the incoming raw water. Proportioning devices control the relative amounts of this chemical mixture and the raw water going into

the downtake. This mixture is sometimes agitated by paddles and sometimes allowed to pass to the bottom of the downtake without agitation, the time in the downtake being such that the chemical reaction is practically completed when the water reaches the bottom of the tank.

After the water leaves the downtake, it spreads over the larger area of the outer shell of the softener, and the upward flow is thus retarded. This upward flow being much slower than the downward flow, the precipitate gradually settles to the bottom. As this precipitate accumulates in the bottom it is removed by a sludging system, usually consisting of a series of pipes covering the bottom of the softener, with small openings such that the sum of the area of these openings does not exceed the total area of the open sludge valve. This valve consists of a quick opening gate valve, in order to get quick movement of the sludge over all parts of the tank bottom.

Excelsior filter

As the treated water flows slowly upward and the scale-forming ingredients are precipitated, the water at the top of the tank becomes clear. It is the writers' policy to have an excelsior filter at the top of the softener which completes the clarification of the water in case any light particles are carried to the top.

There is a great deal of difference of opinion on the excelsior filter. Many say that it is old fashioned and inefficient. The writers began the use of such filters twenty-five years ago and have learned many things in the operation and maintenance of this method of clarifying softened waters. As a result of this experience this method of filtration has been installed in the three latest type plants that have just been completed and put in operation.

The practice here outlined in the water softening process is subject to much variation according to opinions of operators and designers. Some machines may be successfully and conveniently operated from the top so that the chemical solutions flow by gravity as they are measured into the downtake. In some cases it is advantageous to have separate chemical tanks from which the lime and soda ash may be added separately. If alum is used, a third chemical tank is a necessity as this chemical or sodium aluminate should be added after the other two chemicals have reacted.

The velocity of stirring in the downtake or other mixing chamber is an extremely important factor in successful water treating and de-

pends upon the character of the water and the chemicals used. As a rule, violent agitation is injurious to the precipitate formed as it breaks up the floc and does not give a precipitate that will settle as completely as if a longer period of more gentle stirring is used. In such a case a flocculent precipitate is developed, the reaction is completed and when the mixture goes to the settling chamber, the precipitate settles rapidly and completely.

HORIZONTAL TYPE WATER SOFTENERS

Recently several horizontal type water softeners have been designed and installed for railway service, concrete being the material of construction. In these softeners the raw water and chemicals are introduced into a baffled race, the speed of flow being calculated so as to give the proper amount of agitation and the best floc to the precipitate. The chemicals can be introduced at any point in this race that seems to be most desirable, and separately if desired. The time in this mixing chamber is approximately one hour. From this the water is discharged into a settling chamber where it is held for one hour, and in which a very large percentage of the sludge is removed. This chamber has a sludge removal device by which most of the sludge is removed daily. There is attached to this chamber a pumping device for repumping a portion of the sludge. This is added to the mixing chamber where the water is introduced and helps to develop a more desirable precipitate. From the first settling chamber the water passes to a larger chamber where it is held for several hours and from this to the filters.

Some treated waters are used without filtering. This, however, presupposes a large settling capacity and a very complete reaction, together with perfect operation. It is well to have a filter at the end of the process as a matter of safety, so that any slight disturbance in the operation will not permit turbid water to pass through into the storage tank. This is particularly advantageous during times of peak business when it may be necessary to operate the softener beyond its rated capacity.

While sand filters are a more perfect means for clarifying turbid water, it has been found for railroad use that the excelsior filter gives entire satisfaction, costs less to install, less to maintain, and requires less attention from the operator.

OTHER PROBLEMS IN LOCOMOTIVE BOILERS

In the treatment of water for locomotives, there are several important problems to be given consideration other than the mere removal of incrusting solids. Even though the scale-forming ingredients have been removed, there may be difficulty from other sources. A clean boiler may be a fertile field for pitting and corrosion if the elements causing such troubles are present. This problem has and should engage the attention of railroad chemists for a long time. Iron dissolves in water with the evolution of hydrogen, provided the products of the reaction are removed. Otherwise the iron becomes polarized by the hydrogen and the reaction stops. If, however, oxygen is present in the water, the nascent hydrogen will combine with the oxygen and the reaction will continue as long as oxygen is available. Practically all natural boiler feed waters carry oxygen in solution. It is therefore continuously supplied to the boiler. While the amount is very small, ranging from perhaps 5 to 10 cc. per liter, it is nevertheless sufficient to do a great deal of damage.

If corrosion were uniform over the entire interior surface of the boiler, the trouble would not be so aggravated, but owing to the lack of uniformity of the metal, and the fact that there may be strains in flue sheets, fire box, knuckles and seams, the corrosion tends to localize and is then reported as pitting or grooving according to the shape of the corroded area.

The theoretical considerations upon which this thesis is founded are quite familiar and are ably borne out by experimental evidence. This excludes, of course, that corrosion due to acid water, which is not under consideration here.

Various attempts have been made to eliminate the oxygen from locomotive feed water without pronounced success. Open feed water heaters have been used for some time, and there is wide divergence of opinion as to whether or not they eliminate any considerable amount of oxygen. The indications are that much depends on the manner in which the feed water heater is handled. More definite results will be forthcoming when certain tests now running are completed. One of the best remedies at present for oxygen is to carry an excess of caustic soda in the treated water. It is important that this alkalinity be caustic rather than carbonate because there seems to be some evidence that at high temperatures and pressures, sodium carbonate breaks down into caustic soda, organic matter, and free oxygen.

This free oxygen would then be available as a corrosive agent. This is the explanation offered by J. H. Paul in his book on boiler chemistry.

At any rate the writers know that a boiler operating on water containing an excess of sodium carbonate at high temperature and pressure, develops caustic soda and organic matter, and shows some evidence of corrosion of the general, rather than the pitting type. A caustic alkalinity should therefore be maintained in the treated water to prevent this action.

Another difficulty met with in the use of treated water is foaming. Foaming is a function of the concentration of dissolved and suspended solids in the boiler. It may be relieved by frequent use of the blow-off, or the judicious use of anti-foaming compound. The best anti-foaming compounds depend upon castor oil contained in the liquid as an emulsion. A water completely treated by the lime-soda process, carrying a moderate excess of caustic alkalinity, should give less trouble from foaming than waters containing boiler compound or hard waters carrying high dissolved solids. This is because such water contains the smallest amount of dissolved and suspended solids.

Anti-foaming compound should be used sparingly, i.e., not until the water begins to give trouble; thus, the excessive use of compound may be avoided. The writers have seen engines where so much anti-foaming compound has been used that the boiler actually became compound dirty. It is more difficult to control the foaming after that point is reached. The advantages of water treatment in the removal of scale, the increased life of flues and fireboxes, the reduction of engine failures due to boiler troubles and the consequent improvement of railroad operating efficiency, are too well known to require individual comment here. Suffice it to say that with the present trend toward higher boiler pressures, longer engine runs, higher speeds and greater train loads, what is now considered efficient operation would be impossible without adequately treated water. Much has been written of water treatment, and much more has been said, but from the standpoint of the chemical engineer, the real problems of water treatment are solved by faithful field supervision and competent laboratory investigation and control.

SUCCESSFUL OPERATION OF FLUSH VALVES

By E. C. Groner[1]

The flush-valve or flushometer is not a new device. Flush-valves have been in use in various forms for thirty years or longer, but it is only during the last ten or fifteen years that they have been used in large numbers. At the present time, they are being installed at a rapid rate. No figures are available, but the total for the year 1925 must have exceeded 400,000 by a good margin.

They are virtually standard equipment for hotels, apartments, office-buildings, hospitals and clubs. They are being used more and more in public and parochial schools, universities, factories, warehouses and similar buildings. Their use in the smaller and less pretentious apartments and large private homes is greatly on the increase, and architects and owners are specifying them more and more for smaller houses having from one to three toilets.

The waterworks superintendents' professional interest in the flush valve is principally confined to those cases in which larger taps, service pipes and meters are used than are customarily furnished.

Since the flush valve, when installed on direct supply, draws its water from the main through the service pipe, as it requires it—that is to say, since each individual flush valve is not supplied with a storage tank—it is obviously necessary that the service and other piping between the main and each flush valve, shall be ample under the existing pressure to furnish the water to the flush valve at exactly the same simultaneous rates of flow as the flush valve must supply it to the closet bowl or other fixtures.

It is generally agreed that the rate at which water must be delivered to a closet bowl in order to secure a successful flush, is not less than 30 gallons per minute at a maintained pressure which depends upon the character of the closet-bowl used. The great majority of the closet bowls are of the floor-outlet type, that is, they stand upon the floor and discharge through the base. This type of bowl

[1] Installation Engineer, Sloan Valve Company, Chicago, Ill.

ordinarily requires a maintained pressure, or pressure during operation, of not less than 5 pounds per square inch.

Many waterworks superintendents are disturbed when asked to furnish service equipment sufficiently large to deliver water at the rate of 30 gallons per minute to the ordinary small dwelling or other building having about the same plumbing equipment as the small dwelling.

Fashions in plumbing, as in many other things, are changing. The standard of living is becoming higher. Two bath-rooms and sometimes three are now almost universally put into the better class dwellings in place of the single bath-room, of not many years ago. Laundry bibs, sill-cocks, shower-baths, garage sink and other cocks are being increasingly used. It is safe to say that the dwelling of the average American family has two or three times as many water-consuming fixtures as it formerly had. In addition, many fixtures, notably those of the wash-bowl, bath, sink and laundry are of larger size than formerly. I do not mean to say that the daily consumption of the average dwelling has increased in proportion to the increase in the number and size of plumbing fixtures, for it has not. How much it has increased, if at all, can be best answered by waterworks superintendents, but what I do mean to say is that the peak demand has gone up.

Tables 1 and 2 were published within six years from two very reliable sources, giving the demands of plumbing fixtures. With the exception of valve closets (closets with flush valve) all these fixtures are frequently left running for fairly long intervals of time. Overlapping frequently occurs, and the demands of overlapping fixtures may easily equal or exceed 30 gallons per minute, which has already been given as the generally accepted demand or rate of flow of the flush valve.

Owners are often annoyed by the interference of one fixture with the supply to another fixture. Adequate service and piping are required to prevent this. It should be borne in mind that the continuation of the flush of a flush valve is from about 6 to 12 seconds. This maximum demand of 30 gallons per minute is ordinarily the initial demand only, since the flush valve begins to close the instant the handle of the flush valve is released. A certain flush valve that is used in large numbers is put into action by the movement of the handle by the operator, and closes independently of any further action on the part of the operator after delivering a pre-determined amount of water to the closet-bowl.

TABLE 1

Flow of water at plumbing fixtures

KIND OF FIXTURES	FAIR FLOW PER MINUTE	GOOD FLOW PER MINUTE	EXCELLENT FLOW PER MINUTE
	gallons	*gallons*	*gallons*
Kitchen Sink Bibbs	2	4	6
Pantry Sink, High Goose Neck Cocks	2	2	3
Pantry Sink, Large Plain Bibbs	4	6	8
Vegetable Sink Bibbs	2	4	6
Laundry Tray Bibbs	4	6	8
Slop Sink Bibbs	3	4	6
Basin Cocks	2	3	4
Bath Cock (either hot or cold)	3	4	6
Shampoo Spray	½	1	2
Liver Spray	1	2	3
Shower Baths, 5-inch Rain Heads	2	3	4
Shower Baths, 6½-inch Rain Heads	2	3	5
Shower Baths, 8-inch Rain Heads	4	6	8
8-inch Tubular Shower Heads	6	8	10
Needle Baths	20	30	40
Manicure Tables	1	1½	2

By "Actual test at 30 pounds pressure." Buenger, Journal American Society of Heating and Ventilating Engineers, November, 1920. (See Cosgrove, Principles and Practice of Plumbing, p. 194.)

TABLE 2

Water drawn at fixtures (estimated)

FIXTURE	RATE OF FLOW, GALLONS PER MINUTE
Bath	10
Lavatory	5
Tank Closet	5
Valve Closet	30
Shower	5
Sink	10
Laundry Tub	10
Garden Hose	10

Copper and Brass Research Association (Sweet's Catalogue, p. 1457, 17th edition, 1922).

In view of the foregoing, present day conditions demand that service connections and other piping be made sufficiently large to deliver not less than 30 gallons per minute, and preferably not less than 35 to 40 gallons, under the pressures available, to any dwelling that might be classed as better grade.

It must be admitted that the piping connections required for flush valves or direct pressure in small buildings are somewhat larger in some cases than those usually furnished by the waterworks companies for such services. Flush valves are being used at a rapidly increasing rate in small buildings and the waterworks people are receiving more and more insistent demands for adequate service. These demands will have to be met sooner or later.

The main objections to these larger services seem to be two: greater expense for tap and pipe and for meter when used, and greater slippage or unrecorded flow with the larger meters than with the smaller meters. The answer to the first objection is that the owner who wants a larger service, will have to pay for it. The answer to the second objection is largely up to the meter manufacturers and to the inspectors of the water companies. Every meter, no matter how perfect its condition, has some slippage. The tightness of the fixtures determines whether or not this slippage of the meter shall result in unrecorded loss of water. Probably the worse offender in this regard is the tank closet.

On larger buildings the size of the service depends greatly on the peak load demanded by its fixtures. Schools, for instance, demand a larger peak load than any other class of buildings. Apartment buildings above six apartments can use the same size service as is normally used with low-down tank closets, but the piping inside the building is larger for flush valves. Hotels and large office buildings are generally fed from roof tanks or compression systems, and only require services large enough for suction lines for the pumps.

Each building, is a problem in itself. The size of service depends upon the minimum pressure available, peak load demand, elevation of highest fixture above street main, length of service pipe, distance of farthest fixtures from meter, and friction through tap, meter and piping.

When the waterworks superintendent is requested to furnish a service for a building, and he is in doubt as to the size required, it is up to him to have the architect or engineer who has charge of the building, furnish him with a piping layout.

THE ECONOMIC LIMIT OF DEEP WELL PRODUCTION[1]

By John W. Moore[2]

Since the water supply for cities, towns and factories throughout the middle west is largely obtained from wells penetrating the glacial deposits of water bearing sand and gravel and from porous bed rock, any question pertaining to the life or capacity of such wells is of importance.

Three of the most important factors concerning wells are, the first cost, the cost of pumping, and, perhaps most important of all, the life of the well or the period of time over which the well will yield continuously water at an undiminished rate.

Considering wells drilled in bed rock the question resolves itself into a financial one involving the first cost of the wells and pumps and will not be considered further at this time.

Wells penetrating water bearing sand and gravel in which the sand is very fine present problems for which satisfactory solutions have not yet been offered and when properly solved will indicate the number of gallons per minute or the rate of pumpage which such a well can be called upon to deliver safely without shortening its life or diminishing its usefulness.

Assuming that a well penetrating such a water bearing sand and gravel has been properly developed and equipped with a screen of rust resisting material, we then have two main questions which determine the undiminished yield of that well over a period of time. The first is the pumping level of the water in the well, that is creating a difference between the pumping level of the water and the ground water level. This difference, of course, depends upon the capacity of the deep well pump and can be controlled. The second question is the proper velocity or rate of flow of the water through the water bearing sand and gravel to the well.

The practical answer to this second question will indicate the number of wells and the rate of pumpage from each that should be installed in any sand and gravel deposit of whatever degree of fineness

[1] Presented before the Indiana Section meeting, February 17, 1927.

[2] Consulting Engineer, Indianapolis, Ind.

to produce a constant yield of water over a period of years equal to the life of the material of which the well and screen are constructed.

The pumping level of the water compared to the ground water level determines the head or velocity of the water through the sand to the well. This travel of the water to any central point may extend over considerable territory increasing in speed or velocity as the well is approached. The increasing velocity of the water approaching the well is apparently in many instances the ultimate cause of the failure of such wells.

The hydraulic law in reference to the carrying capacity of water in open channels operates no doubt in a modified form and controls the carrying capacity of water flowing through sand and gravel. As the water approaches the well through the sand at an ever increasing velocity the capacity to dislodge and carry forward particles of sand increases enormously and sand is drifted toward and through the screen into the well.

If it were a fact that all of the sand carried forward by the water would pass through the washed gravel surrounding the screen into the well there would be no problem to solve, since the water bearing sand and gravel would be continuously cleaned of the smaller particles thus allowing more free channels through which the water would travel with greater speed, increasing the capacity of all wells regardless of the fineness of the sand through which the water travels.

Unfortunately all of the sand carried forward by the water does not pass through the screen into the well. A physical obstruction seems to be offered to the carrying forward of the fine sand, by the washed gravel around the screen and by the further fact that the openings in the screen are partially obstructed by small gravel This obstruction to the passage of the sand seems to act as a strainer through which the water passes with high velocity, but through which particles of sand of certain sizes will not pass at all. The lodging of each grain of sand increases the difficulty and within a short period of time wells located in such sand and gravel strata build up a wall of sand around the screen through which the water passes with an ever diminishing volume until the usefulness of the well is at an end.

It would seem that the only way to control this so called sand jamming around the screen of a well is to ascertain by experiment the rate of pumpage which a new well will safely stand and which will not produce a velocity of water through the sand sufficient to carry the particles of sand forward toward the well. I do not believe there is any

method by which this can be absolutely determined since the carrying forward of sand may be taking place slowly without any of the sand coming through the screen and showing in the water pumped from the well.

The question of the rate of pumpage in reference to the life of a well system installed in fine water bearing material should, in my opinion, be considered from the standpoint of any other permanent and important development, that is, the number and diameter of wells and the rate of pumpage from each well should be controlled by the first cost and by the length of usefulness of the wells.

The later question, that of the life of the wells, will be controlled by the rate of pumpage and therefore the rate of pumpage seems to be the key to the situation.

In order that I may give an actual example of the carrying capacity or the drifting capacity of water flowing through fine material and thus shortening the life of wells I wish to say that a city in the northern part of the state secures its water supply from sand similar to that found on the shore of Lake Michigan. For many years wells were made in this sand using a screen fine enough to hold back the sand and most of the water. Notwithstanding the fact that the wells had a maximum capacity of from only 30 to 70 gallons per minute it was sufficient to cause the sand to drift into the screen and thereby reduce the usefulness of the well within a very short time.

Three new wells, 10 inches in diameter, were constructed in this same sand around the screens of which washed gravel was deposited. One well was selected and pumped at the rate of 425 gallons per minute with very little sand being carried through the washed gravel and screen into the well. The maximum rate of pumpage was then determined to be not over 200 gallons per minute from each well and so far as my information goes these wells have continued to yield 200 gallons per minute during the last five or six years. I am confident that had the wells been pumped at 400 gallons per minute the sand would have drifted in and destroyed the usefulness of the wells within a comparatively short period of time.

The object of this paper is not to draw conclusions or make recommendations but it is hoped that those who have the opportunity and the inclination will take up this question with the view of determining in a practical way the economic rate of pumpage from wells made in fine material.

ELIMINATING A SOURCE OF ERROR IN THE COLORIMETRIC DETERMINATION OF MANGANESE

By A. C. Janzig[1]

In the determination of minute quantities of manganese by the colorimetric method, a source of error has been observed and a method devised to overcome it. The error has been noted particularly in waters which were highly colored or contained turbidity. The persulfate method as described in "Standard Methods of Water Analysis" (1) was used in these determinations.

The test in substance is: In hot nitric acid solutions containing silver cations, the reaction takes place as follows:

$$2Mn + 5S_2O_8 + 8H_2O \rightarrow 2MnO_4 + 10SO_4 + 16H$$

With interfering substances present, as carbonaceous matter or other insoluble material, a clear-cut comparison of the colors produced is impossible, unless they are filtered out. During the process of filtering off insoluble matter, it was noted that at times a loss of the manganese resulted, due to the deposit of manganese salts on the filter paper.

Certain writers (2) (3) have mentioned the difficulty experienced in completely oxidizing the manganese and also because of its instability during certain valence changes.

They mention the fact that carbon greatly delays the oxidation of manganese and that any other reducing agents should also be absent in the manganese test. According to Lord and Demorest (4) the presence of the silver salt is essential for, if not present, the manganese will be precipitated as manganese dioxide. If too much silver salt is present silver peroxide will precipitate and make the solution turbid. A. Travers (5) mentions the precipitation of manganese dioxide where considerable manganese is present, and that the oxidation to permanganic acid is usually incomplete. If a turbidity of silver chloride appears, Hillebrand (6) advises that the solution

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be agitated and filtered. No mention has been made by these authors of the possibility of a loss resulting in filtering off insoluble matter.

The writer found that when the manganese is completely oxidized to permanganic acid before filtering, no loss of manganese resulted. This was demonstrated by using water to which manganese in definite amounts was added. This is due to the greater stability of manganese in its highest valence, in which case it will not precipitate, but remain in a very soluble form.

In order to overcome the loss of manganese during the process of filtering, the writer carried out the analysis as follows: After the preliminary steps were followed as outlined in Standard Methods, complete oxidation was carried out and then the solution filtered in the presence of the oxidant, ammonium persulfate. Thus an excess of the oxidant was maintained which supplied residual oxygen, overcoming any reducing action which might take place.

Complete oxidation to permanganic acid is indicated by the development of the typical permanganate color which is reddish-purple and is often referred to as the "maximum" color.

The presence of an excess of the oxidant is shown by the evolution of gaseous oxygen.

CONCLUSIONS

In the determination of minute quantities of manganese by the colorimetric method the step which requires greatest care is the oxidation of the element to the heptavalent state. When carried out carefully, interfering substances may be filtered out without a loss of manganese, provided that residual oxygen is maintained during the process of filtration. The persulfate method has otherwise been found satisfactory and with the added precautions given, turbid or highly colored waters may be analyzed with the assurance that accurate results will be obtained.

REFERENCES

(1) Standard Method of Water Analysis, 6th Edition, 1925, p. 50.
(2) McPherson and Henderson: Gen. Chem., 1st Edition, p. 517.
(3) Prescott and Johnson: Qual. Analysis, 5th Edition, p. 177.
(4) Lord and Demorest: Metallurgical Anal., 4th Edition, p. 89.
(5) Travers, A.: Ann. Chem., 6, 56–86 (1926).
(6) Hillebrand, W. F.: Bulletin 700, U. S. Geo. Survey, p. 138.

COMMENTS ON THE MANUAL OF WATER WORKS PRACTICE[1]

By J. W. Ellms[2]

The value of any technical book depends upon the character and amount of information which it contains. The authors who compiled the Manual of Water Works Practice were limited both in the kind and quantity of material which they could use. As stated in the preface, "It has been manifestly impossible to obtain complete agreement on all subjects, particularly those of more detailed technical character." The object has been to "reflect the principles and practices of a fairly adequate cross-section of practitioners in the multiplicity of water works activities." On this basis, the writer feels that the authors have succeeded fairly well.

In any general criticism of the Manual the question may be raised as to whether it has been found satisfactory to its readers, i.e., have those who have used it found that it contained the information for which they were seeking. Probably no two users of a technical book will have the same opinion of its adequacy or inadequacy. Each may find that the particular information for which he may be hunting is not in the book. To a specialist in a particular field, the description and discussion given to his subject may seem quite elementary, while to another not versed in this particular branch of the art, it may appear very informative. If an accurate summary of opinion of the Manual could be obtained, the writer believes that those who specialize in some one field of water works practice would regard the book as more or less inadequate in their own particular branch of work, but generally satisfactory in other respects.

The problem, therefore, becomes one of satisfying both classes of readers. Probably this cannot be done without considerably enlarging the contents of the book and possibly making more than one volume. Financial considerations naturally enter into such a proposition. However, the writer feels that the Manual as it now stands,

[1] Presented before the Central States Section meeting, September 16, 1927.

[2] Engineer of Water Purification and Sewage Disposal, Cleveland, Ohio.

subject to such modifications as seem desirable, may become the basis for a real hand-book of water works practice, which it is believed is the sort of book that all readers desire.

The writer was asked to discuss especially the chapters on the "Treatment of Water." Criticism of any of the topics under this general subject is difficult as long as the authors' objective was presumably a more or less generalized presentation of each subject. Addition or withdrawal of a small amount of subject matter does not materially modify the character of the Manual. However, a very few brief comments on the subject of the "Treatment of Water" as presented in the Manual may be of some interest.

On the 790 pages in the Manual, 16 to 17 per cent of them are devoted to the treatment of water. Out of the six major divisions, excluding the Appendix, this proportion of the whole is perhaps a fair allotment of space. Of the fourteen topics discussed in the 130 odd pages dealing with the "Treatment of Water," the following approximate proportions of the space are given to the several topics:

	Percentage of space occupied
Self-purification of streams, lakes, etc.	9.4
Algae	5.4
Chlorination	12.1
Aeration	4.0
Settlement	3.1
Coagulation	7.3
Rapid sand filtration	12.7
Slow sand filtration	11.2
Double filtration	3.9
Covering reservoirs	1.5
Removal of iron and manganese	3.7
Water softening	9.6
Ultra-violet light and ozone	2.3
Iodization	13.5

The seven subjects, namely, self-purification, chlorination, settlement, coagulation, rapid sand filtration, slow sand filtration and water softening occupy about two-thirds of the text. To iodization, 13.5 per cent of the space is given, leaving about 21 per cent of the text for the remaining six subjects.

The following comments on six of the principal topics may be of value in any revision of the Manual which contemplates maintaining its present character.

Self-purification of streams, lakes and reservoirs. It is difficult to

improve on the language and the thoroughness with which the late Prof. Geo. C. Whipple has explained these natural processes. Certain phases of the subject, however, have received such a thorough exposition by the scientists of the United States Public Health Service, that some summary of the quantitative measurements of de-oxygenation, reaeration and their relation to bacterial pollution would be valuable to the readers of the Manual.

Chlorination. This important subject has been well treated and is entitled to all the space which it occupies. The subject of de-chlorination, however, is hardly more than mentioned in the Manual. This process may not be at present common practice in American water purification plants, nevertheless, there is considerable likelihood of its increasing use. The methods employed in using various anti-chlor compounds, as well as other methods of dechlorinating treated waters, together with the efficiencies and costs, would be helpful to users of the Manual.

Rapid sand filtration. The problem of filter plant loading is discussed in a very general way in the Manual, but its importance warrants considerably more space being given to this subject. By the time another revision of the Manual is made, it is hoped more data may be available for fixing the bacterial standards which water purification plants may be reasonably expected to attain.

Coagulation. The subject of coagulation is well and concisely treated. The employment of alkali aluminates under various trade names for coagulating purposes should receive some consideration, as they have been found useful under certain conditions.

Slow sand filtration. There seems to be no mention of the machine methods for cleaning slow sand filters in which traveling washing machines of the Blaisdell type are used. It is understood that the results of their employment in Philadelphia plants have been quite satisfactory.

Water-softening, zeolites. More might be introduced under this topic on the practical efficiencies of different zeolites used in water softening, and on the costs of the process when compared with the lime-soda process.

Iodization. To this subject there is too much space allotted. It takes up 13.5 per cent of the 130 odd pages given to the treatment of water, or more space than is given to any other topic. It cannot be justified on the score of American practice. While it is a fair presentation of a controversial subject, the extended article printed

could be made much shorter and still give the essential facts. At the most not more than a page or two should be allowed for discussing the entire subject.

In general, the absence of drawings, cuts and diagrams to illustrate and explain the text in the "Treatment of Water" is a real drawback to its usefulness. It is, of course, recognized that the insertion of such material increases the cost. Nevertheless, if readers are to be satisfied, expansion of the Manual into a real hand-book or treatise on American water works practice, is inevitable.

STUDIES OF THE EFFICIENCY OF WATER PURIFICATION PROCESSES[1]

Studies of the bacterial efficiency of municipal water purification plants have formed a logical part of the stream pollution investigations undertaken by the Public Health Service under authority of an act of Congress of 1912. These investigations, having dealt principally with the public health aspects of stream pollution, the safety of public water supplies, and, more especially, the relation between the sanitary quality of such supplies and the permissible degree of pollution of their sources, have been subjects of basic importance for inquiry. A report on these studies by Sanitary Engineer H. W. Streeter, has just been issued as Public Health Bulletin No. 172.

The main objectives of the studies dealt with in this report are the following:

a. An appraisal of the bacterial efficiency of well-designed and well-operated municipal water purification plants treating sewage-polluted river waters; and

b. A determination, if possible, of the maximum limit of bacterial pollution of river water supplies, as delivered for treatment, consistent with the production of effluents conforming to specified standards of bacterial quality.

In the latter connection, reference is made to a limiting standard, recommended in 1914 by the International Joint Commission, defining the maximum permissible density of B. coli in raw waters taken from the international boundary waters of Canada and the United States for purification.

During a period of 13 months in 1915–16, the Public Health Service undertook a preliminary observational study of the Cincinnati and Louisville filtration plants, taking their raw water supplies from the Ohio River. From this study a well-defined relation was found to exist between variations in the bacterial quality of the raw water and concurrent variations in the quality of the effluents obtained at successive stages of treatment, including the final stage.

[1] Reprinted from United States Public Health Reports, Vol. 42, No. 42, October 21, 1927.

From this relationship it was indicated that the maximum B. coli index of the raw water, consistent with the production of a final (chlorinated) effluent conforming to the original United States Treasury Department drinking water standard, was about 630 per 100 cc. The corresponding limit fixed by the International Joint Commission raw water standard was 500 B. coli (index) per 100 cc.

Further studies of the problem were delayed, owing to the war, and were not resumed until 1923, when a collective survey of 17 municipal water-filtration plants was undertaken, 10 of these plants being located along the Ohio River and the remainder on other rivers in the Eastern and Middle Western States. From this survey, the following tentative conclusions were drawn:

1. Under normal conditions of their operation, all of the plants studied have shown a fairly definite relationship as existing between variations in the bacterial quality of their raw-water supplies and concurrent variations in the quality of effluents produced by them at successive stages of treatment.

2. In general, the nature of this relationship has been found to be expressed by the equation $E = cR^n$, in which (R) represents the bacterial content of the raw, or influent, water, (E) that of the effluent water, and (c) and (n) empirical constants.

3. The over-all efficiency of bacterial purification, when expressed in terms of B. coli removal, appears to be influenced to a relatively slight, if any, extent by changes in temperature and other seasonal conditions, or by variations in raw-water turbidity, all other conditions being equal.

4. According to the best statistical evidence afforded by the surveys, as based on the mean performance of the 10 Ohio River plants, the maximum B. coli index of raw river waters of the Ohio River type, consistent with producing a final chlorinated effluent conforming to the revised Treasury Department standard, approximates 5000 per 100 cc. The corresponding maximum raw-water B. coli index consistent with producing *unchlorinated* effluents meeting the same standard was found, however, to average as low as 60 per 100 cc. Plants more highly elaborated than the average, such as those equipped with double-stage sedimentation and coagulation, appear to be able to produce satisfactory chlorinated effluents from river waters having a B. coli index somewhat in excess of 10,000 per 100 cc.

5. Water purification plants operated along the Ohio River are

unable, under existing conditions of pollution of this stream, to produce unchlorinated effluents conforming, as an average, to the revised Treasury Department B. coli standard, though they are able, by the continuous and effective use of chlorine, to produce, for a large part of the time, chlorinated effluents meeting this standard. On the basis of the average limit of tolerance above stated, two of the Ohio River plants surveyed, located, respectively, at Ironton, Ohio, and Ashland, Ky., were indicated as being overburdened by excessive bacterial pollution of the river in the zone from which their raw-water supplies are obtained.

6. With one exception, all of the seven plants surveyed, located elsewhere than on the Ohio River, were able to produce satisfactory final effluents from raw waters having a B. coli index not exceeding 5000 per 100 cc. Two plants of this group, located, respectively, at Albany, N. Y., and Chester, Pa., were shown to be overburdened by excessive raw water pollution, on the basis of the criterion above given.

Aside from those above stated, no final conclusions can be drawn from the surveys described until their results have been checked against the results of experimental studies in progress at this time, and possibly also further surveys of full-scale plants located in other sections of the country. Systematic and well-correlated observations of full-scale plant performance thus far have included no examples of plants found west of the Mississippi River and but one example of plants treating water from the Great Lakes.

Public Health Bulletin No. 172, containing the full report, may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C., at $1 per copy.

A STUDY OF THE POLLUTION AND NATURAL PURIFICATION OF THE ILLINOIS RIVER[1]

A Review by T. C. Schaetzle[2]

For a number of years the United States Public Health Service has been engaged in studies of the pollution of inland streams. Broadly speaking the objectives of these studies have been:

1. To develop practical procedures for the measurement of stream pollution and suitable forms for expression of the degree of pollution encountered.
2. To ascertain the probable effects to be anticipated from increasing pollution loads and to determine the power of streams to recover from such imposed burdens, through the operation of natural agencies.
3. To observe the effects of stream pollution on the public health, as reflected in the quality of water supplies, procurable from polluted sources and as influenced by methods of removal and disposal of domestic sewage and industrial wastes.

The studies discussed in Bulletin No. 171 are concerned primarily with the second of these objectives, the Illinois River being selected for the investigations.

Extensive studies carried on during the years 1921 and 1922 by the United States Public Health Service, in coöperation with the Sanitary District of Chicago, are discussed in this comprehensive report of 6 chapters. The features of the Illinois River and its watershed; the population of the Illinois River watershed, and sources of pollution of the river; hydrometric measurements; methods of procedure in field and laboratory studies; sanitary chemical analyses; and bacteriological studies are reviewed in detail.

The Illinois River watershed comprises a total area of 28,334 square miles and is a part of the eastern Mississippi drainage basin. It is comparatively flat. The natural drainage area has been increased by the construction of the main drainage canal of the Sanitary District of Chicago which withdraws water from Lake Michi-

[1] Public Health Bulletin No. 171, May, 1927, by J. K. Hoskins, C. C. Ruchhoft and L. G. Williams.

[2] Senior Assistant Sanitary Engineer, State Department of Health, Baltimore, Md.

gan and discharges into the head waters of the Illinois River near Joliet. As this canal transports the major volume of sewage from the Sanitary District of Chicago considerable pollution reaches the head waters of the stream. Of a total sewered population on the watershed of approximately 3,400,000 over 80 per cent contributes sewage through the canal in addition to a large portion of industrial waste pollution. The latter, in terms of population equivalents, amounts to about 67 per cent of the total industrial waste pollution on the watershed.

During this study the average rate of discharge from the main drainage canal was 8650 cubic feet per second. This amounts to more than 30 per cent of the total discharge of the Illinois River at the lowest observation station 26 miles from the mouth, but varies with the run off from the drainage area. These percentage figures have gone as high as 70.7 per cent and as low as 9.3 per cent, the latter during flood conditions. To observe the chemical and bacterial content of the river throughout its entire length sampling stations were located at established points not exceeding 25 miles apart. Collections were made at these stations 3 or 6 times weekly. Additional samples were collected from the mouths of the larger tributaries. These collections and examinations were continued over a period of fourteen months. The chemical analyses consisted of determinations of turbidity, alkalinity, dissolved oxygen, both immediate and after five days incubation at 20°C., suspended matter, free ammonia, Kjeldahl nitrogen, nitrogen oxides and oxygen consumed.

The bacteriological examinations consisted of the determination of the bacterial counts on agar plates incubated at 37°C. for twenty-four hours, on gelatin plates incubated at 20°C. for forty-eight hours and an estimation of the B. coli.

The outstanding results of this investigation may best be indicated by the following quotation from the bulletin:

> The sanitary chemical analyses afford a means of estimating roughly the extent of dilution of Chicago sewage in the main drainage canal by water drawn from Lake Michigan. From these data it appears that from 7 to 8 per cent of the flow in the canal is sewage of normal strength diluted with lake water in amounts from 93 to 92 per cent. . . . . As a whole it may be concluded that the sanitary chemical determinations are not sufficiently sensitive to record, accurately, progressive changes that occur in the waters of polluted streams as they flow from point to point. Such examinations are of value, however, in a general way for comparative purposes.

The oxygen dissolved and the oxygen demand determinations are more sensitive indices of the existing condition of organic substances that cause nuisance in polluted watercourses.

The numbers of bacteria in water, especially those of the B. coli group, are generally considered an index of its sanitary condition. Being exceedingly sensitive to various factors of environment, it is of considerable interest to have definite knowledge of the rates at which they disappear in polluted streams or, in other words, the nature and extent of occurrence of natural bacterial purification under various seasonal and physical conditions to which the stream is subjected. The bacteriological observations were, therefore, made with this object in view and for the further purpose of comparing such results with those obtained in previous similar studies of the Ohio River.

Observations, continued throughout an entire year, of the bacterial content of the Illinois River at definitely established sampling stations have supplied sufficient information to evaluate the excessive bacterial pollution of the river by the main drainage canal of Chicago. The density of bacteria is very rapidly reduced in the upper reaches of the river, and, progressing downstream, at slower rates until at Peoria the average numbers growing on agar seldom exceed 4000 per cubic centimeter in summer and 2000 in winter. Pollution contributed by the Peoria district again imposes a considerable bacterial load on the stream, which likewise tends to diminish at subsequent downstream points, until at the mouth the bacterial content of the Illinois compares quite closely with that of the Mississippi River at the junction.

The rates at which the bacteria decrease are dependent on seasonal temperatures, being much more rapid in summer than in winter.

This bulletin presents an excellent compilation of hydrometric, chemical and bacteriological data, together with a large number of charts of which the ones on bacterial purification are especially interesting and instructive. The sketches of the sample collector and sample shipping case as shown in this bulletin seem to be well adapted for the purpose for which they were designed and should be helpful to others engaged in similar studies.

The charts showing the sampling stations and profile along the entire Illinois River, the summarized description of the river prisms, the detailed discussion and charts showing the procedure used to determine the time of flow between sampling stations, the table on estimated average amounts of certain constituents in various industrial wastes per unit of raw material or product, and the detailed chemical and bacterial tables and charts are among the numerous features of this report which indicate the painstaking and thorough manner in which this study was carried out.

The bulletin is concluded with two appendices, one of which is on

the preservation of samples for sanitary chemical analysis. The data and discussion presented should be especially interesting to sewage chemists. Relative to the use of preservatives the following statement is made: "On the whole it appears that the preservation of samples by acidifying with about 1000 parts per million of sulphuric acid is a very simple and highly effective method of procedure."

Charles Henry Rust

Died September 22, 1927

Charles Henry Rust was born at Great Waltham, Essex, England, on December 25, 1852. He was educated at Brentwood Grammar School and came with his family to Canada in 1872. After his arrival in Canada he spent five years on railway location and then entered the services of the City of Toronto attached to the engineering staff under the late Frank Shanly, who was then City Engineer.

In 1881 Mr. Rust was advanced to the position of Assistant Engineer by Redmand J. Brough then City Engineer and Manager of Water Works. In 1883 he was appointed Assistant Engineer in charge of sewers, which position he occupied until 1891. During this period he held also the office of Principal Assistant Engineer. In 1892 Mr. Rust was appointed Acting City Engineer until the appointment of the new City Engineer, E. H. Keating, in July of the same year. This led to his immediate appointment as Deputy City Engineer, holding this office until February 1898 when, upon the resignation of Mr. Keating, he was appointed City Engineer and Manager of the Water Works.

Mr. Rust's greatest interest in municipal engineering always centered around the problems of sewerage and water supply, and under his administration in Toronto many improvements pertaining to better sanitary conditions were originated and carried out. It was during his tenure of office as City Engineer that the cast iron supply main which connected Lake Ontario with the main pumping station was replaced by a tunnel a mile in length, excavated in rock beneath Toronto Harbor; a new intake was installed at a depth 60 feet below the surface of Lake Ontario, and a slow sand filtration plant, with a capacity of 40 million gallons per day, was constructed on the Island separating the harbor from the lake waters. The water supply system in the city was also largely extended to meet the increased demand caused by rapid growth of the city. At about the same time a complete main drainage system and sewage purification plant was installed for the further protection of the water supply of the city.

His duties also included reports on many schemes, which, while requiring a great deal of time and much painstaking study, were never brought to fruition.

He reported at times on water works and sewerage problems for neighboring municipalities and occasionally acted as an arbitrator. Although his services were frequently in demand as a consultant and expert, his routine duties occupied so much of his time that he was unable to accede to many requests for professional advice.

In 1912 Mr. Rust resigned the position of City Engineer of Toronto to accept the position of City Engineer of Victoria, British Columbia. His desire to make this change was heightened by the interesting problems presented by the proposed installation of a new municipal water supply from Sooke Lake. While in Victoria he was requested by the Government to report in conjunction with R. H. Thompson upon the Greater Vancouver Sewerage Scheme. He also reported for the Municipality of Coquitlam upon the Second Narrows bridge, near Vancouver. Six years later he returned to Toronto and became connected with the Toronto Street Railway and Toronto Electric Light Company until these utilities were absorbed by the City. He was identified with the Toronto Hydro Electric System until his death.

Mr. Rust in 1887 was elected as one of the first members of the Canadian Society of Civil Engineers, now the Engineering Institute of Canada. He always took a great deal of interest in its affairs and served in various capacities until in 1911 he was elected President of the Society. In 1902 he was elected president of American Society of Municipal Improvements.

Mr. Rust was elected a member of the American Society of Civil Engineers in 1899 and served as vice-president during the years 1913–1914. For many years he was a member of the Royal Canadian Yacht Club and the National Club of Toronto.

In 1879, Mr. Rust married Alice Preston, who survives him. His kindly and affectionate disposition endeared him to all those who were privileged to know him intimately. His mature judgment, unfailing courtesy and tactful manner fitted him for the numerous high positions which he held in the engineering profession and made him loved and respected by his many business associates.

For many years Mr. Rust was an active member of the American Water Works Association, serving on the Executive Committee during the years 1916, 1917 and 1918. He had joined as an Active Member in 1903.

SOCIETY AFFAIRS

CALIFORNIA SECTION

The California Section Convention at San Jose on October 5, 6, 7 and 8, 1927 again proved a record breaker both in attendance and interest. With the high water mark of 387 to shoot at, set at the San Diego Convention in 1926, San Jose staged the livest and most enthusiastic meeting yet held with a registered attendance of 564 members and guests. Twenty-two members and guests outside of this state honored the convention with their presence, coming from as far away as Canada, New York and Alabama.

Weather conditions proved ideal, warm and balmy in this garden spot of California and did much to make an ideal setting both for the field demonstration staged in the open and for the many pleasure trips arranged especially for the ladies.

The two convention headquarters hotels were completely sold out and the overflow taxed the housing capacity of the other hotels in the city.

The regular 3-day session was extended to 4 days as a trial innovation. The wonderful success that followed gives assurance that this will be a regular feature in the future. The extra day was designed for a twofold purpose, first, a golf tournament and second, a greater opportunity for the members and guests for personal contact and more leisure to review the manufacturer's exhibits. Two hundred and twenty-five registrations at the convention hall in addition to 60 golfers out on the fairways on this opening day proved the tremendous interest created. The winner turned in two rounds of 74 and 72 on the San Jose Country Club links, a course of full championship length.

The San Jose Water Works acted as local hosts and together with the exhibitors were untiring in their efforts to put the convention over the top and certainly succeeded in making the meeting interesting, worth while, instructive and enjoyable to members, guests and exhibitors alike.

The exhibit and convention meetings were held at the Scottish

Rite Temple. The spacious auditorium housed some 52 exhibits, using up all available space. Exhibits were all completed and in place prior to the convention. These were attractive and covered all lines of equipment available to water works practice. Constant crowds from the opeinng day to the windup testified to the intense interest displayed in this feature.

The Convention meetings were held in the lodge room of the temple which proved ideal for the occasion. Two hundred seventy-five delgates attended these sessions. Papers were interesting, short and snappy and several symposium sessions gave opportunity for a great number of the delegates to enter the discussions.

A practical field demonstration of modern water works practice was staged in St. James Park just opposite the convention hall. This was an innovation designed to give all water works men an opportunity to visualize standard practice methods and some especially difficult and unusual service connection problems. Exhibits and demonstrations covered the general ground of cutting and welding fittings, making ½ to 12 inch taps on mains under pressure, gas and electrically welded taps, cement caulked joints, insulated services in galvanized screw, brass and cast iron pipe, electrolysis bonding, solder taps and a 500-pound pressure test on cast iron pipe with caulked cement joints.

This innovation created so much enthusiasm and interest that it is planned to make a demonstration of this character a regular feature of future convention meetings.

On Thursday evening the business dinner was held at the Hotel Sainte Claire and 256 members and guests attended. Reports of retiring officers were presented and the following officers elected for the ensuing year: Chairman, Joseph R. Ryland, to succeed Samuel B. Morris; Vice-chairman, John Burt to succeed Joseph R. Ryland; Secretary-Treasurer, Wm. W. Hurlbut to succeed Paul E. Magerstadt; Executive Committee, Charles Olmstead succeeding John Burt and W. F. Goble succeeding Peter Diederich. In view of the National Convention of 1928 being held in San Francisco next June, it was voted to merge the California Section meeting next year with the national meeting.

The convention was honored by the presence of Beekman C. Little and his family. Mr. Little favored the occasion with an address and brought a hearty message of encouragement and good will from the national officers, and spoke at length on the hopes and plans for the San Francisco convention.

Mr. Clay Miller, former President of the San Francisco Chamber of Commerce, delivered an interesting address paying tribute to the water works engineer and crediting and pointing out how great a part of modern comforts, health, convenience and prosperity are attributable to the technical skill and accomplishments of water works engineering and construction. In concluding, Mr. Miller promised to enlist the whole machinery of the San Francisco Chamber of Commerce in advertising and furthering plans for and assisting the National Convention at San Francisco next year.

The exhibitors' dinner dance was held Friday evening at the Hotel Vendome. Four hundred and forty-four members and guests sat down to dine. The famous "Orpheus Quartet" of Los Angeles sang several selections. Arthur Terry, a talented "cowboy" monologist, entertained after dinner with a clever appropriate patter concerning officials and notables present. An enjoyable dance followed until the small hours of the morning.

On Saturday the San Jose Water Works entertained with an auto trip and barbecue. Two hundred and eighty members and guests participated and had a most enjoyable outing.

The ladies turned out in force for the convention with a total registration of 129. During their free time they were entertained with a theatre party, a country club luncheon and a trip to Stanford University where a special treat was provided in the shape of an organ recital in the famous Stanford University Chapel.

The technical program during the convention follows: "Description of San Jose Water Works System," by Joseph R. Ryland. "Centrifugally Cast High Pressure Concrete Pipe Line for the City of Riverside," by Edward R. Bowen. "Flow Tests from Fire Plugs," by R. C. Stange. "Present Practice in Cross Connections," Symposium. "Removal of Sulphur from Well Water," by Arthur Taylor. "Watershed Protection," Symposium. "Water Main Installation Methods," Symposium. "Various Water Works Jobs for 1927," by I. E. Flaa.

Paul E. Magerstadt,
Ex-Secretary.

ABSTRACTS OF WATER WORKS LITERATURE

Frank Hannan

Key: American Journal of Public Health, **12**: 1, 16, January, 1922. The figure 12 refers to the volume, 1 to the number of the issue, and 16 to the page of the Journal.

The Problem of Concrete Deterioration More Especially with Reference to Its Use for Conduits and in Lining Pipe. John R. Baylis. Am. Soc. Mun. Imp., November 8, 1926. Discusses the fundamental reasons for changes taking place in Portland cement concrete after it has set and specific instances of its deterioration in conduits and pipe lines. Hydrated Portland cement will give up calcium hydroxide to the saturation point of the compound when submerged in water and 90 per cent of the calcium can be extracted by submergence in natural waters. A discussion of the characteristic compounds of hydrated Portland cement and a method of determining the conditions causing this change in composition after exposure to air and water are given. The purpose of calcium sulfate in cement is stated to be to control the set and slow the process of hydration. The exact compound formed by the combination of sulfur trioxide and calcium aluminate when hydrated is unknown, but it is believed to be either a solid solution or surface adsorption thereby forming a film over the aluminium compounds retarding the hydration speed. A gradual carbonating of the alkalies in the cement takes place. This phenomenon occurring near the surface makes possible the use of cement for exposed structures since it prevents the slow leaching of the alkalies from the mass by the penetration of water. The presence of calcium sulfo-aluminate needle crystals in concrete is shown to be a contributing factor in concrete weakening due to the rearrangement of the particles forming the mass with resultant pressure within itself. The statement is made that a water having a sulfur tri-oxide content greater than 4 p.p.m., which includes most natural waters, will give up sulfates to the concrete if the calcium hydroxide component is reasonably high. These conditions indicate that the decomposition of *old* concrete is not necessarily due to poor workmanship or materials but can be caused by chemical changes. A discussion of the use of cement in lining of iron water mains is given and suggestions offered as to the effective thickness of the coat for protection of the pipe in corrosive and non-corrosive water. Photographs showing cement under conditions as discussed are given together with curves illustrating analytical data.—*Edward S. Hopkins.*

Progress of Electrometric Control Methods in Industry. H. C. Parker. Ind. Eng. Chem., **19**: 660–7, 1927. The advantage of electrometric measurements is given. Instruments of this type have found application, not only for the usual acidimetric and oxidimetric analyses of the scientific laboratory,

but also in the practical control of such industries as mercerizing cotton, manufacturing sulfuric acid and sugar, and in studies of waste disposal, water works, and power plants. Apparatus suitable for such work is described.—*Edward S. Hopkins (From Chem. Abst.).*

Manganese Interference in the Ortho-Tolidine Test for Available Chlorine. Edward S. Hopkins. Ind. Eng. Chem., **19**: 744–6, 1927. Attention is called to the fact that unstable salts of manganese will oxidize *ortho*-tolidine and produce the characteristic yellow color. Entire reliance cannot be placed upon this test for available chlorine if manganese is present in a water supply. The possible chemical formulae for manganese under such conditions are discussed.—*Edward S. Hopkins.*

Effect of Velocity on Corrosion of Steel under Water. R. P. Russell, E. L. Chappell and A. White. Ind. Eng. Chem., **19**: 65–8, January, 1927. A review of previous work and of theoretical factors is presented. Tests on pieces of steel suspended in water in steel tubes of varying diameter were conducted over periods of time running from 48 hours to 2 weeks. This work indicates that the corrosion of steel under water increases with increasing velocity of water provided metal is covered with rust.—*Edward S. Hopkins.*

Use of Lime in Water Softening and Water Purification. Charles P. Hoover. Ind. Eng. Chem., **19**: 567–70, May, 1927. In addition to its softening qualities, attention is called to the sterilizing action of excess lime in water treatment. A selective action for B. Coli is suggested, tables being given to show that after 5 hours contact using excess causticity this organism is killed. Elimination of color, iron, turbidity, and odor and increased sedimentation efficiency are claimed. Modern practice is to soften to point of precipitation of magnesium and then add excess of carbon di-oxide gas to precipitate calcium hydroxide followed by filtration. Gas is obtained by burning coke, oil, etc. Possible also to use "split" treatment, neutralizing excess lime with carefully controlled portions of raw water. Operating cost of such treatment is given.—*Edward S. Hopkins.*

Natural Sodium Bi-Carbonate Waters in the United States. W. D. Collins and C. S. Howard. Ind. Eng. Chem., **19**: 623–4, May, 1927. A review of about 8800 analyses is given. The Atlantic Coastal Plain is considered the best area for sodium bicarbonate water. A chart is given illustrating data given.—*Edward S. Hopkins.*

Treatment of Water to Prevent Corrosion. John R. Baylis. Ind. Eng. Chem., **19**: 777–81, July, 1927. The possible treatment of a water supply to prevent corrosion is presented and a review of current thought upon corrosion is given. The question of protective coatings for iron pipes is discussed and it is shown that zinc will be dissolved in water at a pH of 6.5 or less but does not corrode very readily at a pH of 7.5. Corrosion of a fresh iron surface is not prevented even by an alkaline water, but such a water will build a system of protective coating and finally retard it completely. Water at solubility

equilibrium of calcium carbonate and containing over 25 p.p.m. alkalinity will not corrode pipe. A curve is given showing various concentrations of alkalinity for pH values of solubility equilibrium of calcium carbonate. Water above or on this curve will build up protective coating for pipe, below it, it will be corrosive. Pitting is discussed and data are presented to show that a pit is always acid. Cement lined pipe will give longer life than the usual bituminous coatings, but corrosive water will eventually destroy this protection. The evidence produced indicates that water containing alkalinity to the point of saturation on the calcium carbonate curve offers fairly good protection to iron pipes and if kept near that curve will not fill lines with incrusting material. —*Edward S. Hopkins.*

Cement Lined Water Mains. HARRY Y. CARSON. Ind. Eng. Chem., **19**: 781–3, July, 1927. This paper considers the factors in water supplies causing "red water" conditions and discusses value of cement lined pipe to prevent internal corrosion of water mains. Replacement of calcium hydroxide by ferric hydroxide is believed to prevent erosion of the cement and give indefinite life to the pipe. Methods of manufacture are discussed and data after about 50 years of service in corrosive water are given.—*Edward S. Hopkins.*

Recarbonation of Softened Water. CHARLES P. HOOVER. Ind. Eng. Chem., **19**: 784–6, July, 1927. Water softened with lime may deposit calcium carbonate in pipe lines with decrease of capacity, or choke filter beds by formation of "balls" resulting in poor operating conditions. Such a condition is overcome by adding carbon-dioxide to such a supply thereby converting the slightly soluble calcium carbonate to the highly soluble calcium bi-carbonate. Such practice is being conducted in numerous places in this country, operating conditions of certain plants being quoted together with a description of the apparatus, as well as a comparison of cost of various fuels for the production of carbon di-oxide upon a plant scale.—*Edward S. Hopkins.*

Surface Waters of North Carolina. MARGARET D. FOSTER. Ind. Eng. Chem., **19**: 855–6, July, 1927. A detailed analysis of the surface waters of this state and a table showing these data in a convenient form are given.—*Edward S. Hopkins.*

Paradox of Corrosion and Protective Film Theory. T. FUJIHARA. Ind. Eng. Chem., **19**: 1008–9, September, 1927. A microscopical study indicates that pure metals are more corrodible when exposed to a drop of water than the more impure commercial variety. It is concluded that initial corrosion is faster with impure iron than with the electrolytic, but as protective films are formed the corrosion is retarded. Microphotographs and curves are presented.—*Edward S. Hopkins.*

Color Diffusion in Endo Agar. ELIZABETH F. GENUNG and LUCY E. THOMPSON. Jour. Bact., **14**: 139–56, August, 1927. Interesting information concerning the reliability of Endo medium for differentiation of B. coli, B. aërogenes,

and B. typhosus is given. The failure of this medium is due to the re-appearance of color upon standing, producing false reading of the organisms. Studies were made in an attempt to explain this condition. Commercial peptones were investigated; some brands produced this return of color, others did not. A pH value of 7.3 is suggested as the correct reaction value. The theory of the test as given is that color production in the colony of the colon group is due to an acid-aldehyde reaction and not to the presence of lactic acid alone.—*Edward S. Hopkins.*

Investigations of Chemical Reactions Involved in Water Purification. Illinois State Water Survey, Bulletin **22**: 133 pp., 1920–25. Titration curves, by means of the hydrogen electrode, are given for some common carbonates and bicarbonates, and with the same equipment the precipitation of magnesium, calcium and aluminum has been studied. The solubility of aluminum hydroxide, determined over a wide pH range, gave data for a recalculation of the solubility product and the isoelectric point, giving a minimum solubility range of pH 5.5 to 7.8. A pH of 6.0 favored maximum color removal. From two surveys of filtration plants in Illinois, data were collected on residual alumina with relation to pH, the minimum amounts being found between pH 6.0 and 7.8. Samples from various filtration plants were analyzed with particular attention to the chemical composition of the alum floc, and an experimental filter was operated over a wide pH range to supplement the laboratory and field data. In addition, the solubility product of magnesium hydroxide was determined, and studies are reported on the effect of heat in a commercial lime-soda softener.—*A. M. Buswell.*

The Mineral Waters of Basilicata. Luigi Parlati. Il notiziario chim.-industriale **1**: 116–7, 1926. From Chem. Abst., **20**: 2474, August 10, 1926. Continued investigation shows numerous springs not already described. Some of these are utilized therapeutically.—*R. E. Thompson.*

Chemical and Chemico-Physical Investigations of the Water of the Baths of Roselle, Grosseto. R. Nasini, C. Porlezza and A. Donati. Ann. chim. applicata, **16**: 99–126, 1926; cf. C. A., **19**: 366. From Chem. Abst., **20**: 2474, August 10, 1926. Composition of water given. Aside from possible value of mineral ingredients, its temperature (38.5°), its radioactivity (0.0402 Maché units per liter) and its free carbon dioxide content (86.66 p.p.m.) may account for the therapeutic value.—*R. E. Thompson.*

Do Spring Waters Containing Carbon Dioxide and Hydrogen Carbonates Activate Amylases? M. Loeper and A. Mougeot. Compt. rend. soc. biol., **92**: 569–71, 1925. From Chem. Abst., **20**: 2505, August 10, 1926. Spring waters containing carbon dioxide and hydrogen carbonates have no amylolytic action, but strongly activate amylases of saliva and pancreatic juice. Effect is not due to alkali present, since solution of a hydrogen carbonate does not behave in like manner. Removal of carbon dioxide by boiling does not destroy activating effect. This excludes also possibility of biological action. Effect cannot be due to radioactivity nor to influence of pH, since latter is considerably changed on boiling.—*R. E. Thompson.*

Spring Waters Containing Hydrogen Carbonates and the Activity of Invertase from Beer Yeast. A. Mougeot and V. Aubertot. Compt. rend. soc. biol., **92**: 1504–6, 1925; cf. preceding abstract. From Chem. Abst., **20**: 2505, August 10, 1926. Effect of spring waters on invertase depends simply on pH.—*R. E. Thompson.*

Corrosion of Pipe Lines and Protective Coverings. F. R. McGrew. Petr. Devel. & Techn. in 1925, 521–5. From Chem. Absts., **20**: 2477, August 10, 1926. Only absolutely effective method of protection known is to encase in concrete; but it has several serious economic disadvantages. Highly encouraging results were obtained with Dearborn Chemical Company's "no-ox-id" compound, new pipe to which it has been applied showing no signs of corrosion after 3 years. Badly pitted pipe which was treated with "no-ox-id" showed no signs of further corrosion at bottom of pits. F. N. Speller. Ibid., 526–8. After considerable investigation, chrome iron (13–25 per cent chromium) was only material found to be non-corrodible to pronounced degree, but it costs about 60 cents per pound. Tests of pure iron, as uniform and homogeneous as could be made, did not show marked difference from less uniform materials, showing that problem is not one of homogeneity, but of keeping media which cause corrosion, and particularly that cause irregularity of corrosion, away from pipe. Remarkable anti-corrosion results in salt water have been obtained with open-hearth steel containing 1 per cent copper.—*R. E. Thompson.*

Chlorinated Potable Water and Its Applicability in Canning Vegetables. H. Serger. Z. Untersuch. Lebensm., **51**: 125–32. 1926. From Chem. Abst., **20**: 2546, August 10, 1926. Water which had been treated with chlorine in amounts ranging from 0.1 to 1 gram per cubic meter was found suitable for canning vegetables, quality of product being unaffected and tests for free chlorine negative.—*R. E. Thompson.*

Testing Progress of Chemical Reactions, etc. R. S. McNeil. U. S. 1,587,782, June 8. From Chem. Abst., **20**: 2552, August 10, 1926. Material undergoing treatment, e.g., water under treatment with zeolites, is passed through passage and there is added to material a substance, e.g., ammonium oxalate, sodium carbonate, or soap, which effects a restriction of passage upon occurrence of change for which test is to be thus made in the material, e.g., when compounds of calcium and magnesium, etc., have not been removed from the water and form a precipitate.—*R. E. Thompson.*

Waste Water of Dye Works. E. T. Ellis. Dyer & Calico Printer, **55**: 32–3, 1926. From Chem. Abst., **20**: 2585, August 10, 1926. Purification of the water and recovery of values contained.—*R. E. Thompson.*

Recovery of Furnace Dust, Treatment of Mine and Domestic Waste. W. M. von Bernewitz. Blast Furnace & Steel Plant, **14**: 21–2, 1926. From Chem. Abst., **20**: 2636, August 20, 1926. Application of thickeners to neutralization of mine water, and to water softening described.—*R. E. Thompson.*

Corrosion of Iron. W. G. Whitman. Chem. Rev., 2, 421–35, 1926. From Chem. Abst., **20**: 2648, August 20, 1926. Modern electrochemical theory of corrosion of iron is reviewed. Dissolved oxygen, pitting velocity, and effect of dissolved salts are discussed.—*R. E. Thompson.*

Protection of Iron Against Corrosion by Lead (the Galvanization of Iron by Lead). A. V. Blom. Z. angew. Chem., 39: 555–6, 1926. From Chem. Abst., **20**: 2648, August 20, 1926. Iron may be protected by painting with linseed oil suspension of lead pyrosol in lead oxide previously prepared in electric oven. Lead remains in surface of sheet iron after paint has been wiped off. Photographic plates show that lead pyrosol in lead oxide is effective while lead pyrosol in lead suboxide is without effect. Complete theory of mechanism is to follow in later paper.—*R. E. Thompson.*

A Method of Measuring Rates of Corrosion of Iron in the Presence of Carbon Dioxide and Air and the Influence of Electrical Potentials on Such Rates. A. Hayes, E. L. Henderson, C. E. Staneart and G. H. Brodie. Proc. Iowa Acad. Sci., **31**: 280–1, 1924. From Chem. Abst., **20**: 2648, August 20, 1926. Cylindrical samples of wrought iron were subjected to action of water saturated with gas mixture. Four per cent carbon dioxide mixed with air dissolves 1 gram of iron per sq. cm. of exposed surface in 735 days, while it requires 1927 days with air alone. Fall of 0.25 millivolt per cubic centimeter increased rate of corrosion 28 per cent, but 0.025 millivolt had no appreciable effect. Methods of eliminating corrosion of this type given.—*R. E. Thompson.*

Method of Reducing the Corrosion of Water Conduits Consisting of Pipes of Two Different Metals. H. Cassel. Korrosion u. Metallschutz, **1**: 75, 1925. From Chem. Abst., **20**: 2649, August 20, 1926. Considerable corrosion takes place at copper-iron joints in water conduits. This may be greatly reduced by inserting short length of lead piping between copper and iron pipes. The lead piping becomes coated with thin layer of lead oxide and acts as inert substance and, on account of separation of iron and copper and the poor conductivity of ordinary water, no current flows between the two metals; hence, corrosion is slight.—*R. E. Thompson.*

The Rusting of Iron. VI. A. Kistyakovskii. Z. Elektrochem., **31**: 625–31, 1925. From Chem. Abst., **20**: 2647, August 20, 1926. First stage in rusting of iron is formation of thin oxide film, which corresponds to passive state and can be intensified by contact with oxidizing solutions. Further rusting occurs when film is broken. Five general states of iron surface can be determined, with different potentials. Relative specific volume of metal and oxide determines its adherence. Presence of electrolytes like carbon dioxide accelerate removal of protective oxide film.—*R. E. Thompson.*

McCulloch's Observations Regarding the Rapid Corrosion of Metals by Acids Within Capillaries. U. R. Evans. J. Am. Chem. Soc., **48**: 1601–3, 1926; cf. C. A., **19**: 3471 and following abstract. From Chem. Abst., **20**: 2648, August

20, 1926. Localized corrosion of steel beneath rubber bands when exposed to 1.4 N. hydrochloric acid is found to occur only in presence of oxygen and hence is differential aëration effect. From same cause the center of an iron rod is dissolved, leaving a shell.—*R. E. Thompson.*

The Rapid Corrosion of Metals by Acids Within Capillaries. LEON McCULLOCH. J. Am. Chem. Soc., **48**: 1603–4, 1926; cf. C. A., **19**: 3471. From Chem. Abst., **20**: 2648, August 20, 1926. Reply to EVANS (preceding abstract). Iron rivets wrapped with rubber bands showed at times 50 per cent more corrosion in air-free 1.4 N. hydrochloric acid than in air-saturated acid. Capillary pitting was noticeable in both cases but more distinct in presence of air.—*R. E. Thompson.*

Investigation of the Effect of Differential Aeration on Corrosion by Means of Electrode Potential Measurements. A. L. McAULAY and F. P. BOWDEN. J. Chem. Soc., **127**: 2605–10, 1925. From Chem. Abst., **20**: 2648, August 20, 1926. Data on e.m.f. of zinc and iron surfaces. Potential differences are characteristic of differential aëration and differ with amount of corrosion which has occurred.—*R. E. Thompson.*

Porosity and Intensive Corrosion. Experiments on Commercial Sheet Zinc and Other Materials. U. R. EVANS. J. Soc. Chem. Ind., **45**: 37–44T; Bull. Am. Zinc Inst., **9**: 22–7, 32–7, 40, 55, 1926. From Chem. Abst., **20**: 2648, August 20, 1926. Pitting or localized corrosion of zinc in sodium chloride, magnesium sulfate and potassium sulfate was noted. Conclusion: Point corrosion follows and is due to capillary channels in original metal whether rolled or cast. Similar conclusion drawn for iron.—*R. E. Thompson.*

The Influence of Segregation on the Corrosion of Boiler Tubes and Superheaters. G. R. WOODVINE and A. L. ROBERTS. Iron and Steel Inst., 1926 (advance proof), 4 pp; Engineering, **121**: 646–7. From Chem. Abst., **20**: 2649, August 20, 1926. Boiler tubes are usually made from non-piping steel, and in most instances show segregation. Billets of such steel often split in piercing. Tubes showing segregation corroded severely during one year's service, while homogeneous tubes corroded very little under same conditions. Tubes of specially made steel free from segregation have shown better corrosion resistance in practice than ordinary tubes.—*R. E. Thompson.*

The Problem of the Origin of Punctiform Corrosion Phenomena. ERJK-LIEBREICH. Korrosion u. Metallschutz, **1**: 67–9; Chem. Zentr. 1925, II, 2024. From Chem. Abst., **20**: 2649, August 20, 1926. According to McKAY the appearance of punctiform corrosion in iron pipes is related to potential difference arising from differences in concentration of solution in pipes. Since products of corrosion are alkaline, this theory must be rejected. It is more likely that break in uniform coating of rust inside pipe is caused by impurities or by chlorides. Since hydrogen set free by oxidation of iron is occluded by rust, a galvanic element hydrogen | liquid | iron is formed, which causes fur-

ther corrosion at particular location and consequent local cavities.—*R. E. Thompson.*

The Utilization of Rustless Steel in Hydraulic Installations. Krupp. Monatsh., 7: 85. 1926. From Chem. Abst., **20**: 2647, August 20, 1926.—*R. E. Thompson.*

Consumption of Soap in Cleaning the Human Body in Water Containing Waste Liquor from the Potash Manufacture. J. H. Vogel. Kali, **20**: 166–73, 1926. From Chem. Abst., **20**: 2713, August 20, 1926. Amounts of hardness precipitated by washing hands in tap water with and without additions of waste liquor were determined. Only small amount of hardness is precipitated with ordinary amount of soap; complete precipitation of total hardness does not take place on increased use of soap; precipitated amount is practically independent of amount of hardness present; precipitated hardness is mainly that of lime, average ratio of original lime-magnesia hardness being 100:103 and of the precipitated only 100:21. Suggested that precipitated magnesia hardness in experiments with addition of waste liquor originates both from natural and supplied excess. Tjaden's calculation of increased soap consumption because of increased hardness from potash waste liquor thus appears erroneous.—*R. E. Thompson.*

Influence of Industrial Waste Waters on Rivers with Special Reference to the Schunter. von Morgenstern. Centr. Zuckerind., **34**: 278–9, 1926. From Chem. Abst., **20**: 2713, August 20, 1926. The Schunter receives wastes from brown-coal mine, potash works, and sugar mill. First is characterized by high content of ferrous iron and sulfate, second by high chlorides and magnesia and third by organic matter. In December, 1924, many fish died and a nuisance was created. This was definitely traced to poisonous effect of magnesium chloride in potash wastes.—*R. E. Thompson.*

Ammonia-Chlorine Disinfection Process. W. Olszewski. Pharm. Zentralhalle, **67**: 312–3, 1926. From Chem. Abst., **20**: 2713, August 20, 1926. Process developed by Race in 1917–18 involving use of gaseous ammonia and chlorine has been studied in its application to swimming pools and found to possess twice the disinfecting power of chlorine alone.—*R. E. Thompson.*

Radioactivity and Chemical Composition of Mineral Waters of the Hammam (Baths) of the Ouled Ali. Pouget and Chouchak. Compt. rend., **182**: 1480–1, 1926; cf. C. A., **20**: 702. From Chem. Abst., **20**: 2784, September 10, 1926. One spring gave 28.2 millimicrocuries of Rn; the other, 5.4. Chemically they contain principally carbonates, calcium, and sulfates. These "eminently curative" waters, with temperatures of 44.5° and 52.0°, are used almost exclusively by natives.—*R. E. Thompson.*

Determination of Sodium; Several Applications. L. Barthe and E. Dufilho. Compt. rend., **182**: 1470–3, 1926. From Chem. Abst., **20**: 2802, September 10, 1926. Method of Blanchetière (C. A., **17**: 3006) is very suitable

for determination of sodium in mineral water. Organic matter should be destroyed before applying test and phosphoric acid removed by precipitation as uranyl salt.—*R. E. Thompson.*

The Sinter of the Salt Baths of Nauheim. Fritz Ensslin. Ber. Oberhess. Ges. Natur- u. Heilkunde, Giessen, **10**: 13 pp., 1925; Chem. Zentr., 1926, I, 1523. From Chem. Abst., **20**: 2806, September 10, 1926. Probable origin of salt water of springs discussed. Study of deposit of components present in the sinter showed that there is partial loss of carbon dioxide, oxidation of ferrous iron by atmospheric oxygen, and deposition of ferric hydroxide. With the latter is precipitated the greater part of the arsenic, phosphate, and alumina, after which are deposited carbonates of lead, zinc, calcium, and manganese and finally calcium sulfate. Silica remains relatively long in solution. Subsequently there is further deposition of zinc carbonate with appearance of zinc bicarbonate in the water.—*R. E. Thompson.*

The Hot Springs at Nasavusavu. C. H. Wright. Analyst, **51**: 235–7. 1926. From Chem. Abst., **20**: 2806, September 10, 1926. Analysis of water in 1921 compared with analyses made in 1876, 1877–8, and 1879. Mineral matter consists chiefly of calcium chloride and sodium chloride, together with small quanities of magnesium, potassium, sulfate and silica.—*R. E. Thompson.*

Cause and Prevention of Embrittlement of Boiler Plate. S. W. Parr and F. G. Straub. Prov. Am. Soc. Testing Materials, 1926, No. 26 (preprint), 28 pp. From Chem. Abst., **20**: 2814, September 10, 1926. Embrittlement of boilers has occurred only when sodium carbonate is present in feed water either naturally or as result of treatment, and where only small amounts of sulfate are present. It occurs only in seams and rivets and is not related to quality of metal. Embrittlement cracks are characterized by following grain boundaries. Fatigue and corrosion cracks cut across the grain. Embrittlement has been duplicated in laboratory only by stressing steel above yield point in hot solutions of 35 per cent sodium hydroxide. In practice, embrittlement is prevented by adding sulfuric acid (or aluminium sulfate-magnesium sulfate with a settling tank) to feed water to make ratio sodium sulfate: sodium hydroxide over 2.—*R. E. Thompson.*

Metals to Resist Corrosion or High Temperatures. H. J. French. Trans. Am. Electrochem. Soc., **50** (preprint): 30 pp. 1926. From Chem. Abst., **20**: 2814, September 10, 1926. Discussion of some of principal characteristics and typical applications of metals used industrially to resist high temperatures or corrosion. Those considered include commercially pure copper, aluminum, lead, tin, silver, nickel, and iron and alloys in which these are predominating elements. Report is primarily résumé of previously published but widely scattered information, and somewhat more emphasis is placed upon industrial applications than on laboratory test data.—*R. E. Thompson.*

Corrosion-Resistive Metals. C. E. Sholes. Textile Colorist, **48**: 264, 1926. From Chem. Abst., **20**: 2814, September 10, 1926. Manganese bronze recommended for chlorine bleaching.—*R. E. Thompson.*

Filtering and Purifying Water. C. H. Perry. U. S. 1,590,120, June 22. From Chem. Abst., **20**: 3054, September 20, 1926. Mechanical features.—*R. E. Thompson.*

Potable Water in the Rural Localities of the Basso Reggiano. Carmelo Bellini. Staz. sper. agrar. ital., **58**: 5–13, 1925. From Chem. Abst., **20**: 2886, September 10, 1926. Superficial, ordinary wells, which are frequently polluted, are being replaced by deep, tubular wells of iron pipe (8–10 cm. diameter). Peaty strata at even considerable depths give rise to ammonia, which passes into the water. Of 25 ordinary wells only one contained potable water, while of 12 tubular wells, only one contained non-potable water.—*R. E. Thompson.*

Remark Upon the Paper of G. Alsterberg "Method of the Determination of Elementary Oxygen Dissolved in Water in the Presence of Nitrous Acid." H. Noll. Biochem. Z., **165**: 497–9, 1925; cf. C. A., **20**: 790. From Chem. Abst., **20**: 2887, September 10, 1926. Modification of method of Winkler, as given by Lehmann and Noll (C. A., **12**: 964) serves well for determination of oxygen in presence of nitrites.—*R. E. Thompson.*

Magnesium Chloride and Magnesium Sulfate in the Daily Food. J. H. Vogel. Kali, **20**: 181–4, 1926. From Chem. Abst., **20**: 2881, September 10, 1926. Discussion of potability of water containing magnesium chloride and sulfate originating from potash works' waste. Any household using commercial ocean salt is increasing "hardness" of meals with these same salts. From amounts of chloride found in human excretions it is assumed that daily consumption per adult averages 15 grams sodium chloride, containing 90 mgm. magnesium chloride and 123 mgm. magnesium sulfate. These amounts are far in excess of those ingested with water containing normal amounts of potash waste liquor, and have been consumed for centuries and proved harmless.—*R. E. Thompson.*

Oxidizability of Water as Measured by the Kubel-Tiemann Method and the Determination of the "Chlorine Number." K. Keiser. Gas- u. Wasserfach, **69**: 41–3 65–9 (1926). From Chem. Abst., **20**: 2887, September 10, 1926. Determination of oxidizability of water containing organic substances can generally be carried out by Kubel's permanganate method, or by chlorination method of Froboese (C. A., **15**: 913). If, however, humic substances or protein degradation products are present, chlorination method is the only accurate one, permanganate having no effect on these. Treatment of water with small amounts of chlorine, sufficient to destroy bacteria, does not affect oxidizability as measured by permanganate consumption. Efficiency of filtration process is increased and life of filter beds prolonged by preliminary chlorination of the water.—*R. E. Thompson.*

The Importance of the Chemical Composition for Judging Ground Water. J. Hug. Monats. Bull. Schweiz Ver. Gas- u. Wasserfachm., **5**: 1–4, 21–3, 41–6, 66–8; Chem. Zentr., 1925, II, 2222. From Chem., Abst. **20**: 2886, September 10,

1926. Subjects include Swiss regulations for drinking water, relation between ammonia content and geological nature of a water, between oxygen and salts, between hardness and infiltration zones, etc. Concluded that chemical analysis is capable of lending valuable information on internal condition and origin of water, which, together with geologic features, enables adequate judgment to be made.—*R. E. Thompson.*

The Red Lake at Witzenhausen on the Werra, a Natural Colloidal Water. E. Wedekind. B. d. Verein für Naturkunde zu Cassel 1925, 7 pp.; Chem. Zentr., 1925, II, 275. From Chem. Abst., **20**: 2887, September 10, 1926. Data given on this red-colored water, which behaves completely like a colloidal solution.—*R. E. Thompson.*

Alumina Cement. Hans Eisenbeck. Chem.-Ztg., **50**: 165–7, 202–4, 239–41, 246–8, 1926. From Chem. Abst. **20**: 2902, September 10, 1926. Tests included tensile and compressive strengths of 1:3 standard sand mortar from 5 hours to 28 days; compressive strengths of mixes from 1:3 to 1:15 at various ages; bond strength between mortars made from various cements; exposure of portland and alumina cement mortars to solutions of various acids, bases, and salts; effect of frost action on strength and on temperatures in interior of specimens; compressive strengths of 1:3 mortars made with mixtures of portland and alumina cements.—*R. E. Thompson.*

Disposal of Beet-Sugar Waste Waters, With Reference to the Expected National Regulation of Waste Disposal. Prütz. Deut. Zuckerind., **51**: 481–2, 513–5, 1926. From Chem. Abst., **20**: 2917, September 10, 1926. Possible methods for purification of battery and press wastes are: (1) Fermentation, either with or without precipitation of lactic acid by lime. This latter method absorbs proteins in precipitate and produces excellent fertilizer. Effluent is apt to be too acid for small streams, and should be sprayed on fields. Method is simple and generally applicable. (2) Chemical treatment with ferrous sulfate or alum and lime. This is expensive, requires accurate control and gives precipitate not suited for fertilizer use. (3) Purification by anaërobic bacteria. This is complete, but must be controlled, and produces much hydrogen sulfide. Effluent must be sprinkled on fields with deep drains. (4) Sprinkling alone. This is rarely successful, requires very large areas, and tends to produce algal growths in streams. Beet flume and washer waters usually require settling only. Sterilization of waste waters with chlorine before reuse in factory gives promise of being successful.—*R. E. Thompson.*

Determination of Iodine in Natural Waters. H. W. Brubaker, H. S. Van Blarcom and N. H. Walker. J. Am. Chem. Soc., **48**: 1502–4, 1926. From Chem. Abst., **20**: 3053, September 20, 1926. Method used by Hunter for determination of small amounts of I in thyroid was adapted to determination of iodine in water. Iodine is oxidized to iodate by boiling with sodium hypochlorite; acidified with phosphoric acid; potassium iodide added and iodine liberated titrated with sodium thiosulfate.—*R. E. Thompson.*

Clarification, Sterilization, and Filtration of Water Supplies, Trade Wastes, and Other Waters. Water and Water Eng., 28: 185, 1926. From Chem. Abst., 20: 3053, September 20, 1926. Clarifier, claristerilizer and clar filter have been designed by F. W. Brackett and Co. Ltd., for rapid, simple filtration. Filtration takes place by upward flow through two or more filters, area of each being increased and size of filtering material decreased at each stage of process. —*R. E. Thompson.*

Lactose-Fermenting Bacteria. FRED BERRY. Am. J. Pub. Health, 16: 590, 1926. From Chem. Abst., 20: 3053, September 20, 1926. Results of 640 samples show that bacteria which do not produce gas (10 per cent) in 48 hours in lactose broth are not significant.—*R. E. Thompson.*

Charleston Water Works Notes. J. E. GIBSON. Public Works, 58: 294–5, 1927. A new 2 million gallon ellipsoidal bottom elevated tank, 80 feet in diameter, 35 feet high, and elevated 85 feet was put into service.—*C. C. Ruchhoft* (*Courtesy Chem. Abst.*).

Shepaug Tunnel, Waterbury Waterworks. GEORGE E. CLAPP. Public Works, 58: 295–300, 1927. The construction of a new water tunnel about 7.5 miles long containing two 45 degree bends without sinking shafts is described. —*C. C. Ruchhoft* (*Courtesy Chem. Abst.*)

Modern Methods of Water Purification. C. ARTHUR BROWN. Water Works, 66: 337–8, 1927. A short review of modern methods.—*C. C. Ruchhoft* (*Courtesy Chem. Abst.*).

Durham's New Water Works. D. M. WILLIAMS. Public Works, 58: 197–203, 1927. A dam 80 feet high was built across the Flat River one mile above the pumping station forming an impounding reservoir of 547 acrea containing 4600 million gallons. This dam will ensure to Durham, N. C., an abundant supply of water at all times and the surplus water will be converted into power for pumping water to the filtration plant and other uses.—*C. C. Ruchhoft* (*Courtesy Chem. Abst.*).

Metering Services in Small Towns. CHARLES ADE. Water Works, 66: 303–4, 1927. A discussion of the water waste problem and the economics of universal metering as applied to small towns.—*C. C. Ruchhoft* (*Courtesy Chem. Abst.*).

A New 300 m.g.d. Pumping Station in Chicago. ANON. Water Works, 66: 215–21, 1927. The water is obtained from the Edward F. Dunne Crib and carried by the southwest lake and land tunnel by gravity to the pumping station. Four centrifugal pumps designed to deliver 300 m.g.d. against a head of 150 feet are driven by compound steam turbines. Power is developed in boilers fired by forced draft underfeed stokers. The discharge system, boiler room, auxiliary equipment, and building are described.—*C. C. Ruchhoft* (*Courtesy Chem. Abst.*).

How the Chicago Water System Grew. Anon. Water Works, 66: 209–14, 1927. The first municipal system was constructed in 1852 and consisted of an 8 million gallon per day pumping engine, a 30-inch wooden intake to the suction well in the lake, 30 miles of cast iron pipe and 3 elevated wrought iron reservoirs of ½ million capacity each. The first intake tunnel 2 miles long was completed in 1867 and marked the beginning of the present system which has grown at a phenomenal rate and now includes six intake cribs, 70 miles of tunnels, 11 pumping stations, and 3,400 miles of cast iron mains. The present supply is not a first class one as measured by present standards because considerable pollution enters the lake at several sources in the Calumet region and chlorination is the only treatment used. Filtration is being seriously considered and an experimental filtration plant is under construction.—*C. C. Ruchhoft* (*Courtesy Chem. Abst.*).

Colorimeter for Precise Matching of Solutions in Nessler Tubes. John H. Yoe. Ind. Eng. Chem., 19: 1131, October 1927. A new colorimeter has been developed, a detailed description being given.—*Edward L. Hopkins.*

Comparison of Commercial Chemical Limes. J. S. Rogers. Ind. Eng. Chem., 19: 1157–9, October, 1927. A survey of the various commercial limes was undertaken as a basis for the writing of specifications. The methods used in analysis, a table of analytical results and certain limits of impurities are given. Limits for SiO_2 and Al are set at 1 per cent and for Fe at 0.5 per cent. —*Edward S. Hopkins.*

Water Softening as Practiced at Oberlin Ohio. W. H. Chapin. Ind. Eng. Chem., 19: 1182–7, October, 1927. At this softening plant after-precipitation of carbonates has caused clogging of mains after twenty years of operation. Monocarbonate alkalinity is always present and figures frequently indicated caustic alkalinity also. The precipitation trouble was eliminated by 30 days storage in reservoir after softening with lime whereby excess carbonates are precipitated. This plan has made subsequent filtration unnecessary. A very elementary description of the process and chemical reactions involved is given. —*Edward S. Hopkins.*

Water Softening at Springfield, Ill. Chas. H. Spaulding. American City, 36: 4, 472–474, April, 1927. A description of the new softening plant consisting of two mechanical agitators, providing 42 minute mixing period at average circular flow of 0.8 feet per second, two Dorr clarifiers in parallel, with a detention period of 1½ hours, settling basins with 4-hour detention period, carbonating chambers with a 30-minute period and rapid sand filter units. Lime is unloaded and conveyed by a vacuum conveyor to bins from which it falls by gravity to the slackers and wet feed equipment. The cost of treating the water is $16.22 per million gallons exclusive of fixed charges.—*Chas. R. Cox.*

What Is Sound Water-Works Financing? Caleb Mills Saville. American City, 37: 1, 41–44, July, 1927. A detailed discussion of rates, valuation, income, costs, and reserve funds pertaining to water works.—*Chas. R. Cox.*

Wallingford Water Supply and Pine River Filtration Plant. Wm. A. MacKenzie. American City, 36: 3, 347–350, March, 1927. A new two million gallon per day rapid sand filtration plant was placed in use recently at Wallingford, Conn. Raw water is aërated, coagulated with alum, settled, filtered, and chlorinated. Only two of the designed four filter units were built at a cost of $36,000. Complete plant to cost $43,000.—*Chas. R. Cox.*

Sterilization of Municipal Water Supply of Horton, Kan., by Ultra-Violet Ray. N. T. Veatch, Jr., American City, 36: 3, 306–308, March, 1927. A brief description of the ultra-violet ray sterilization unit at the rapid sand filtration plant of Horton, Kan. The raw water is of low turbidity and the filters are efficient. Conditions therefore suitable for this rather rare form of water sterilization. The filtered water is of satisfactory quality, therefore the tabulated data do not permit estimation of effectiveness of final treatment under more adverse conditions.—*Chas. R. Cox.*

Fire Protection Factors Affecting the Insurance Rating of a Community. Lawrence Day. American City, 36: 1, 53–57, January, 1927. A discussion of the factors used in deriving the "base rate" for fire insurance in municipalities, namely, water supply, fire department, fire-alarm system, police department, building laws, hazards, structural conditions, and climatic conditions. Water supply is considered of more importance than the fire department, judging from the relative "points" allowed in the scoring system, namely, 1700 against 1500.—*Chas. R. Cox.*

Recent Improvements in the Water Supply of Nyack, N. Y. Nicholas S. Hill, Jr., American City, 36: 6, 776–782, June, 1927. A detailed description of an interesting rapid sand filtration plant of 1.5 m.g.d. normal capacity recently built to replace slow sand filters. The coagulation basins are equipped with "ridge and valley" constructed floor. One-inch orifices, located in the valleys and spaced 2 feet apart, discharge sludge into 6-inch vitrified pipes spaced 3 feet apart and discharging into a collecting pipe fitted with gate valves. The strainer system consists of half-round cast iron pipes 6 inches in diameter and placed 9 inches center to center on cast iron spacers, which provide a continuous one-half inch opening on both sides. The four filter units are on one side of the pipe gallery, thus providing natural lighting of the gallery and simplicity of construction.—*Chas. R. Cox.*

Some Unusual Operating Features of Centralia's Filtration Plant. R. S. Rankin. American City, 36: 2, 172–175, February, 1927. The rapid sand filtration plant of Centralia, Ill., was placed in operation in 1926. Mud turtles greatly reduced the low-lift pump capacity until the intake screen was repaired. Red water trouble, unusual in Illinois, developed in the summer of 1926. The large impounding reservoir was drawn upon very heavily in 1925 and heavy growth of vegetation occurred on large uncovered area. Decay of this vegetation led to excessive content of carbon dioxide. The aërators remove most of this gas, but lime treatment also had to be practiced.—*Chas. R. Cox.*

Water-Works Pumping Equipment of Omaha's Metropolitan Utilities District. American City, 36: 2, 201–202, February, 1927. Description of largest horsepower centrifugal pumping unit for water works service, and the various water-wheel driven auxiliary equipment.—*Chas. R. Cox.*

New Combined Light and Water Plant of Martins Ferry, Ohio. CLAYTON DE VAULT. American City, 36: 2, 213–215, February, 1927. A description of new sources of water supply, consisting of 5 Layne wells, and of the new boiler and generator plant recently installed.—*Chas. R. Cox.*

The Modern Filtration Plant at Goldsboro, N. C. W. C. TOLER. American City, 36: 4, 471–472, April, 1927. A description of the new rapid sand filtration plant of 3,750,000 g.p.d. designed capacity.—*Chas. R. Cox.*

Water-Works Development in Palm Beach and West Palm Beach, Fla. MALCOLM PIRNIE. American City, 36: 6, 737–744, June, 1927. Historical sketch of water supply system of Palm Beach with brief description of new rapid sand filtration plant and construction details.—*Chas. R. Cox.*

Study and Extension of the Distribution Systems of Water-Works. LAWRENCE C. HOUGH. American City, 36: 5, 606–609, May, 1927. A plea for careful planning of distribution systems to economically serve the future population.—*Chas. R. Cox.*

A Pressure Filter Plant for a City of Three Thousand. American City, 36: 5, 621–622, May, 1927. A brief description of a pressure filter plant recently installed at Superior, Nebraska.—*Chas. R. Cox.*

The Electrically Operated Pumping Station, Kansas City, Mo. E. W. HARVEY. American City, 36: 6, 794–796, June, 1927. A description of the electrical equipment at three new motor-driven, centrifugal pumping stations.—*Chas. R. Cox.*

The New Water-Supply System of Ridgewood, N. J. E. J. FORT. American City, 36: 6, 816–820, June, 1927. Description of new deep well supply, where motor-driven, centrifugal, deep well pumps are utilized in 5 new wells.—*Chas. R. Cox.*

Proposed Water-Supply Improvements at Westfield, Mass., Involve Large Earth Dam. C. A. FARWELL. American City, 36: 6, 821–824, June, 1927. Details of a proposed earth dam 80 feet high to impound 500 million gallons of water.—*Chas. R. Cox.*

The Water-Supply and the City Limits. LOUIS BROWNLOW. American City, 37: 1, 27, July, 1927. A note upon the value of sanitary or water districts, embracing suburban areas, in solving the vexing problem of water supply for areas immediately outside incorporated municipalities.—*Chas. R. Cox.*

Control of Algae Growths in Outdoor Swimming Pools. CHESTER COHEN. American City, **37**: 2, 167–168, August, 1927. $CuSO_4$ in ordinary doses was unsuccessful in controlling algae in outdoor swimming pool. As chlorine was applied daily for disinfection purposes in amounts sufficient to maintain 0.3 p.p.m. excess, the dose was increased to 0.6 p.p.m. with very satisfactory results. Before the pool was used next morning the excess chlorine had disappeared. The dose was again increased two weeks later when a regrowth of algae occurred.—*Chas. R. Cox.*

NEW BOOKS

Water Supply. By DR. ADOLPH HEILMANN. 211 pages, 66 cuts, 1927. A. Ziemsen, publisher. A volume on the scientific and technical principles of water supply by the director of the water works of the City of Dresden, Germany. The author discusses the collection and distribution of water in all of its aspects. The book is systematically arranged and contains a number of interesting examples and methods of attack on the general problem. A bibliography of a helpful nature is included. Like most books prepared abroad, it contains relatively little of modern American practice. The material is helpful, however, for those readers who are interested in comparing foreign procedure and practices with those in America.

CONTENTS

CONSTITUTION OF THE AMERICAN WATER WORKS ASSOCIATION

ARTICLE I

Name

The name of this Association, a corporation organized under the laws of the State of Illinois, shall be "The American Water Works Association."

ARTICLE II

Object

The object of this Association shall be the advancement of knowledge of the design, construction, operation and management of water works, and the encouragement, by social intercourse among its members, of a friendly exchange of information and experience.

ARTICLE III

Membership

Section 1. Members of this Association may be either Honorary Members, Active Members, Corporate Members, or Associate Members.

Section 2. An Honorary Member shall be one whose scientific or practical knowledge in matters related to public water supply, or whose accomplishments in that field of endeavor, shall entitle him to especial recognition by the Association. Honorary Members shall have the same privileges as Active Members, but shall not be required to make any payments for the support of the Association.

Section 3. An Active Member shall be either a superintendent, manager or other officer of a municipal or private water works; a civil, mechanical, hydraulic or sanitary engineer, a chemist or bacteriologist, including those acting technically as such for, and employed by, Associate Members of the Association; or any qualified person

engaged in the advancement of knowledge relating to water supplies in general.

Section 4. A Corporate Member shall be a water board, water commission, water department, water company or corporation; national, state or district board of health or other body, corporation or organization interested or engaged in public water supply work, and shall be entitled to one representative whose name shall appear on the roll of members and may be changed at the convenience or pleasure of the represented Corporate Member upon written request to the Secretary, and who shall have all of the rights and privileges of an Active Member.

Section 5. An Associate Member shall be either a person, firm or corporation, engaged in manufacturing or furnishing materials or supplies for the construction or maintenance of water works. An Associate Membership shall entitle the holder to be represented by one person on the floor at each meeting but such representative shall not be entitled to vote or take part in any discussion unless permission is given by unanimous consent of the members present.

Section 6. When an Active Member so changes his vocation that were he to apply for membership he would be classed as an Associate Member, he may continue as an Active Member with all the privileges of that grade, except that he shall not be eligible to any elective office in the Association.

Section 7. Associations or societies which are primarily organized to promote the advancement of the water supply art in any of its branches, and to furnish to their members information relating thereto, shall be eligible to election by the Executive Committee as an affiliate of the American Water Works Association. The Association desiring to become an affiliate shall submit an application to the Executive Committee, and upon the application receiving the approval of a majority of the Executive Committee said Association shall be deemed elected an affiliate, and shall remain an affiliate until it withdraws, upon due notice received from it, or through it being dropped as an affiliate by a majority vote of the Executive Committee. An affiliate shall pay no dues, shall exchange publications, and its members who are qualified to be Active Members of the American Water Works Association, may become so without payment of any initiation fee, but shall pay the yearly dues.

ARTICLE IV

Admission and Expulsion

Section 1. The Executive Committee may, at its discretion, at the request of any member, present the name of any person qualified for Honorary Membership, to the Association for election to that grade of membership; but the Executive Committee must, upon the written request of twenty-five members, so present the name of any such person to the Association.

Section 2. Any person, firm, corporation or water department desiring to become an Active, Corporate or Associate Member must make application for the grade of membership sought, upon the blank form provided by the Association. Each application must be endorsed by two members of the Association, shall embody a concise statement of the applicant's qualifications for membership and be accompanied by the initiation fees and dues as hereinafter provided. All applications must be forwarded to the Secretary, who shall submit them to the Membership Committee, as soon as possible.

A majority affirmative vote of the Membership Committee shall elect to Active, Corporate or Associate Membership subject to review by the Executive Committee.

Section 3. No member whose dues are in arrears shall receive the publications of the Association until such dues are paid. Members in arrears for one year shall be dropped from the roll by the Secretary.

Section 4. Any member who has been suspended for non-payment of dues may be reinstated by the Membership Committee upon payment of all back dues. He shall then be entitled to receive such back numbers of the publications of the Association as may have been withheld from him on account of non-payment of dues, and are not out of print.

Section 5. Any member of any grade may be expelled from the Association for cause, upon the recommendation of the Membership Committee, adopted by a two-thirds vote of the members present and voting at any annual convention.

Section 6. Any member may retire from membership by giving written notice to that effect to the Secretary, provided that he pay all dues to that date, unless released from said payment by the Executive Committee.

ARTICLE V

Fees and Dues

Section 1. Each Active Member shall pay an initiation fee of Five Dollars, and annual dues of Ten Dollars, provided that any Active Member in good standing who has paid dues continuously for thirty years shall be exempt from payment of further dues. No initiation fee shall be required from a member in good standing of an affiliate association who is elected as an Active Member.

Section 2. Each Corporate Member shall pay an initiation fee of Ten Dollars, and annual dues of Fifteen Dollars.

Section 3. Each Associate Member shall pay an initiation fee of Ten Dollars, and annual dues of Twenty-five Dollars.

Section 4. The fiscal year of the Association after the calendar year of 1924, shall begin on January 1st and terminate on December 31st. Annual dues shall be payable in advance and shall be due on January 1st, the first day of the fiscal year covered by said dues. It shall be the duty of the Secretary to notify each member on or before December 31st of the amount due from said member for the ensuing year.

Section 5. Any newly elected member shall be entitled to all of the publications of the Association that are distributed to the members during the year for which he has paid dues. Members elected later than October 1st shall not be required to pay the annual dues for the current year, but if they do pay said annual dues they shall be entitled to all publications to which members in good standing are entitled for that year.

Section 6. In case any application for membership shall he rejected the initiation fee and dues which accompanied the application shall be returned to the applicant.

ARTICLE VI

Officers

Section 1. The officers of the Association shall be a President, Vice-President, Treasurer, Secretary, and Editor of the Association's publications. The offices of the Secretary and Editor may be combined at the discretion of the Executive Committee.

Section 2. There shall be an Executive Committee in which the government of the Association shall be vested. It shall consist of

the President, Vice-President, Treasurer, Secretary, Editor, the Chairman of the Finance Committee, the latest two living Past Presidents and nine Trustees elected to represent the nine Districts hereinafter established, one Trustee to be elected from each District to serve three years. The President and Secretary of the Association shall be the President and Secretary of the Executive Committee. In 1924 one Trustee shall be elected from District 1, to serve one year, one Trustee from District 5 to serve two years, one Trustee from District 9 to serve three years, one Trustee from District 4 to succeed the present Trustee whose term expires in 1924, and one Trustee from District 8 to succeed the present Trustee whose term expires in 1924; and every year thereafter three Trustees shall be elected in the Districts in which the terms of the incumbents expire.

SECTION 3. The following Districts are established for the purpose of territorial representation:

District 1 shall consist of the Dominion of Canada.

District 2 shall consist of the States of Maine, New Hampshire, Massachusetts, Rhode Island, Vermont and Connecticut.

District 3 shall consist of the State of New York.

District 4 shall consist of the District of Columbia and the States of New Jersey, Pennsylvania, Delaware and Maryland.

District 5 shall consist of the States of Virginia, West Virginia, Tennessee, North Carolina, South Carolina, Georgia, Florida, Alabama and Mississippi.

District 6 shall consist of the States of Kentucky, Ohio, Indiana and Michigan.

District 7 shall consist of the States of Louisiana, Arkansas, Missouri, Kansas, Oklahoma, Texas, Nebraska, Colorado, New Mexico, Arizona, Utah and Nevada.

District 8 shall consist of the States of Wisconsin, Minnesota, Illinois, Iowa, South Dakota and North Dakota.

District 9 shall consist of the States of Wyoming, Idaho, Montana, Washington, Oregon, California and all other Territories of the United States and all territory outside of the United States except the Dominion of Canada.

The boundary line of these Districts may be changed by majority vote of the Association at any time when it becomes necessary or desirable to do so in order to preserve an equitable territorial representation.

Should any Trustee be thrown into another District by changes made in the boundary lines or by change of residence, he shall serve

out his term of office and be accredited as the representative either of his old District or of the District in which he resides, as the Executive Committee may determine.

SECTION 4. After 1925, each member may cast his vote for his District representative by sending to the Secretary his ballot enclosed in an envelope, on the back of which is to be endorsed: "Ballot for member of the Nominating Committee for District No............ ....(Signature)." The ballot is to be worded substantially as follows: "I hereby vote for...................... to represent District No. ...., as member of the Nominating Committee of the American Water Works Association for 19 ...., ... (Signature)." If a member has sent in his ballot, he may, upon application to the Secretary, withdraw his letter ballot. Members may vote in person at the convention.

Immediately following the adjournment of the second session of the first day of the annual convention, there shall be elected a member of the Nominating Committee to represent each District. Due notice of such election shall be given prominence in the program of the convention, which shall be mailed to the members at least three weeks previous to the opening day of the convention. The Trustee representing the District shall preside at the election for his District, and if the Trustee for any District is not present at the convention, a member of that District, designated by the presiding officer of the convention, shall act as Chairman for such district. The Secretary shall present to each Chairman the ballots received by him from members in the respective Districts, and such ballots, together with the votes of those present, shall be counted. The member of each District receiving the greatest number of votes shall be declared to be elected as the member of the Nominating Committee to represent the District. In case of a tie vote, the members present at the meeting shall decide the tie by selecting one of the members receiving the tie vote. The Chairman shall immediately report in writing to the Secretary the name of the member elected to represent the District. The members of the Nominating Committee so elected, together with the latest living Past President at the convention, who shall be Chairman, shall constitute the Nominating Committee, to place in nomination candidates for the offices to be filled for the following year.

The Nominating Committee shall hold a meeting on the second day of the convention, previous to which time suggestions of names

to fill the various offices may be made by the members of the Association to the members of the Nominating Committee, or by leaving same with the Secretary of the Association prior to the meeting of the Committee. Names sent to the Secretary by mail at any time prior to the meeting of the Committee shall also be presented to the Committee for consideration. Nominations shall be by majority vote of the Nominating Committee, who must place in nomination one, and may place two, candidates for each office to be filled, provided that any candidate so nominated for the office of President, Vice President, or Treasurer shall have been a member of the Executive Committee or any one of the four standing Committees provided for in Article VIII, Section 1 for at least two years.

On or before January 10th the Nominating Committee shall report its list of nominees to the Secretary of the Association, who shall before the first day of February cause to be mailed to the membership the list of nominees selected by the Nominating Committee. At any time prior to noon on the first day of March of each year additional nominations may be made by request to the Secretary, signed by at least twenty-five Honorary, Active or Corporate members, and upon the receipt of such request the Secretary shall, after acceptance of the nomination by the candidate, add such additional nominees to the final ballot to be prepared by him. The nominees of the Nominating Committee shall head such final ballot for each office, and any additional nominees for the respective offices shall be placed under the nominees of the Committee in alphabetical order.

Section 5. When more than one is nominated for any of the offices to be filled the election shall be by letter ballot. When a letter ballot is required the ballot shall, prior to March 15th, be mailed to each member of the Association entitled to vote. Each member shall be entitled to vote for one candidate for President, one candidate for Vice President, one candidate for Treasurer and three candidates for Trustees. The ballot shall be sealed separately in a special ballot envelope. This ballot envelope shall be enclosed in a larger envelope and forwarded to the Secretary. The signature of the member voting shall appear on the outer envelope.

When a letter ballot is necessary the Secretary with two canvassers appointed by the President shall meet at a time and place directed by the President, and shall open and count all ballots cast by persons entitled to vote. No ballot shall be counted if received later than noon of the seventh day previous to the beginning of the annual convention. When only one candidate is placed in nomina-

tion for each office to be filled the report of the Nominating Committee shall be considered as an election.

The result of the canvass for President, Vice-President, Treasurer, and Trustees shall be declared by the President at the annual meeting on certification of the canvassing board. The members who shall have received the highest number of votes cast for the several offices shall be declared elected. If there be a tie vote the President shall order a vote to be taken in the annual convention to decide which person of those who shall have received the same number of ballots shall be chosen.

The terms of the officers so elected shall be as follows: for the President, Vice-President, and Treasurer, each one year beginning with the close of the last day of the annual convention and ending the last day of the next annual convention, or until their successors shall have been chosen; for the Trustees, three years beginning with the close of the last day of the annual convention, or until their successors shall have been chosen.

Section 6. Before the close of each annual convention the Executive Committee elected to serve during the year ensuing shall organize and elect a Secretary and an Editor to serve until the close of the next annual convention, or until their successors are chosen.

Section 7. In case of inability of the President to perform the duties of his office, his position shall be temporarily filled by the Vice-President, and in case of inability of the Vice-President, his position shall be filled by one of the Trustees, the order of precedence being governed by priority in date of election as Trustee, or if the dates of election be the same, by priority in date of the admission of such Trustees to membership in the Association.

Section 8. All vacancies in office, except as provided in Section 7 hereof, shall be filled by vote of the Executive Committee for the unexpired term of said office as soon as practicable after said vacancy occurs.

Section 9. The President, Vice-President and Trustees shall be ineligible to election to the same office for consecutive terms.

ARTICLE VII

Duties of Officers

Section 1. The President shall have general supervision of the affairs of the Association, and shall preside at all meetings of the Association and of the Executive Committee at which he may be present.

SECTION 2. The Executive Committee shall be the legal representative of the Association and as such shall have full control of the management of the affairs of the Association, subject to the control of the Association in regular convention; it shall make the necessary arrangements for the convention and shall have power to expend the funds of the Association or to invest the same, but must not incur indebtedness beyond the funds in the hands of the Treasurer and Secretary. The Executive Committee shall have power to prepare and enforce, for the conduct of the business of the Association, by-laws not in conflict with this Constitution. It shall hold an annual meeting at least one hour before the opening session of each annual convention. Other meetings shall be held at the call of the President or of any three members of the Executive Committee.

All questions in the Executive Committee shall be decided by a majority vote and seven members shall constitute a quorum. The Executive Committee may vote by letter upon questions submitted by the President and Secretary.

The Executive Committee may designate an Administrative Committee to be composed of the President, Treasurer, Chairman of the Finance Committee, and such other members of the Executive Committee as may be selected, but the Secretary shall not be included as a member of the Administrative Committee. The Administrative Committee may act for the Executive Committee, but the scope of action of the Administrative Committee may be limited by the Executive Committee. Action taken by the Administrative Committee shall be reported monthly by the Secretary to the Executive Committee.

SECTION 3. The Treasurer shall have charge of the funds of the Association, shall pay bills against the Association on order of the Finance Committee certified by the Secretary and shall make a report of the expenditures and of the funds of the Association at the annual convention.

SECTION 4. The Secretary shall be an Active Member of the Association. It shall be his duty to attend all conventions and meetings of the Association and of the Executive Committee; prepare the business and duly record the proceedings thereof. He shall see that all moneys due the Association are carefully collected, and shall promptly pay the same to the Treasurer. He shall personally certify the accuracy of all bills or vouchers to the Finance Committee.

He shall, at the annual convention, make a report of the receipts and of the condition and affairs of the Association.

He shall conduct the correspondence of the Association and keep a full record of the same.

Section 5. The Editor shall have charge of the printing and distribution to all the members, of the Proceedings and Transactions of the Association and shall perform such other duties as are assigned to him by the Executive Committee.

The publications of the Association shall be copyrighted so far as is practicable and proper.

ARTICLE VIII

Committees

Section 1. There shall be four standing Committees, the Finance Committee, the Membership Committee, the Publication Committee and the Convention Committee. The members of each shall be appointed by the incoming Executive Committee. They shall serve for one year beginning with the close of the last day of the Annual Meeting or until their successors shall have been appointed. Special Committees may be appointed at any time by the President.

Section 2. The Finance Committee, which shall consist of three Active Members, shall audit and approve all bills before they shall be paid by the Treasurer. It shall examine the books of the Secretary and of the Treasurer annually or more often, and shall audit the same and report upon the same to the Executive Committee. This Committee shall have general supervision of the finances of the Association, making such reports thereon to the Executive Committee as the exigencies of the case may require or as directed by the Executive Committee or by the Association at its annual convention.

Section 3. The Membership Committee, which shall consist of three members, shall examine the qualifications of and vote upon all applicants for membership nominated in due form, and report its action to the Secretary.

Section 4. The Publication Committee shall consist of the Editor, one representative for each of the National Divisions, one representative of the Standardization Council, and such other members as may be selected from the membership at large by the Executive Committee. The Publication Committee shall have control of

the publications of the Association including the program of the annual conventions, and shall see that all publications and papers are edited before publication, and whenever possible, before presentation.

The Committee may call to its aid members of the Association or others who have had special experience in the subject treated, to advise in regard to any paper, or to discuss the same, and may return any paper to its author for correction or amendment.

No papers containing matter either readily found elsewhere, especially advocating personal interests, carelessly prepared, purely speculative, or foreign to the purpose of the Association shall be accepted. The Committee shall prepare rules which, when approved by the Executive Committee, shall govern the preparation, presentation and publication of all papers and such other matters of similar nature as the best interests of the Association may require.

SECTION 5. The Convention Committee, which shall consist of three members, one of whom shall be the Secretary, shall investigate all invitations to hold conventions of the Association, satisfying itself that the places extending the invitations have proper facilities for the accommodation of the members and guests, for holding the meetings of the Association with its National Divisions, and for exhibits by Associate Members. This Committee shall invite the Convention Committee of the Water Works Manufacturers' Association to cooperate with it. The Committee shall prepare and send to all cities extending invitation to hold conventions a form containing such questions as may be necessary to properly inform the Committee as to the convention facilities offered. The information shall include a diagram of the rooms offered for meeting rooms, Committee and Division rooms and exhibition space, also a list of available hotels with guaranteed rates and the number that each will accommodate, points of interest to water works people, and entertainment, if any, offered.

All invitations for holding conventions shall be filed with the Convention Committee by February 1st of each year. The Convention Committee shall report its findings to the Executive Committee at the annual convention. If no invitations be received, it shall be the duty of the Convention Committee to report to the Executive Committee its recommendation as to the place which should be designated for the next annual convention. The Execu-

tive Committee shall determine the place for holding said convention. The Committee, or one or more members of the Committee, may, as soon as practicable after the place for holding convention has been selected, visit such place and ascertain whether the guarantees can be fully carried out, and whether it is a suitable place for holding a convention of the Association; also, if the place is approved, to make the necessary arrangements for holding the convention. If after such visit, it is the judgment of the Committee that the place is not suitable, or does not offer proper facilities, or for any other reason it would not be for the best interests of the Association to hold its convention there, the Committee shall immediately report its findings to the Executive Committee, with its recommendations as to the meeting place for the next annual convention. The expenses of the Committee or members of the Committee, in making such visits, to be borne by the Association, on the basis of an allowance of four cents per mile travel.

ARTICLE IX

Meetings

Section 1. The annual convention of the Association shall open on such Tuesday as the Executive Committee may designate and at such place as shall have been designated by the Executive Committee after receiving the recommendation of the Convention Committees.

Section 2. The Executive Committee shall have power to change the place of meeting as in its judgment the interests of the Association may demand.

Section 3. The date of the Annual Convention shall be fixed by the Executive Committee not less than seventy days in advance of the meeting, and such date shall be printed on all ballots for the nomination or election of officers.

ARTICLE X

Sections and Divisions

Section 1. Local Sections may be established by the Executive Committee on receipt of a written request to that effect signed by twenty Active or Corporate Members of the Association, residing in the territory within which the Local Section is desired.

SECTION 2. National Divisions consisting of Engineers, Superintendents, Chemists and Bacteriologists, Accountants or other classes of persons included in the membership of the Association, may be established by the Executive Committee on the request of thirty members. Any member of the Association may register in any National Division of the Association in which he is interested.

SECTION 3. Such Sections and Divisions, which shall consist only of members of this Association in good standing, shall elect their own officers and committees, subject to confirmation by the Secretary of the Association as to their standing in the Association, and may make any rules for their government not inconsistent with the Constitution and By-Laws of the Association, but these rules must first be approved by the Executive Committee.

SECTION 4. Each Local Section as soon as established, and after its rules have been approved by the Executive Committee, may, with the approval of the Finance Committee, annually receive from the Treasurer of the Association for local use not more than 25 per cent of the annual dues paid to the Association by the members of said Local Section as shown by the books of the Association on the first day of November of each year, unless the Executive Committee increases the amount allowed to any Local Section, the amount of such increase to be determined by the Executive Committee and to be allowed only when in the judgment of the Executive Committee the work undertaken by the Local Section is such as to be of material benefit to the Association. Unless the Executive Committee increases the amount allowed, the total money received by any Local Section for any one fiscal year shall not exceed the sum of $300. Local Sections having small memberships shall be entitled to receive from the Association $100 in any one fiscal year, even though the allotted 25 per cent of the annual dues paid to the Association by the members of the said Local Section does not amount to $100.

Each National Division when established, and its rules and constitution have been approved by the Executive Committee, may, with the approval of the Finance Committee, annually receive from the Treasurer of the Association a sum not exceeding $100 for Division Expenses.

The Treasurer of each Local Section or National Division shall forward to the Secretary of the Association his application endorsed by the presiding officer of the Section or Division for such portions

of the said sums above specified as may be needed, and upon receipt of such application the Secretary shall request the Finance Committee to authorize the Treasurer of the Association to pay such sums to the Treasurer of the Section or Division. These moneys may be used by the Section or Division only in payment of necessary operating expenses, such as printing, stationery, postage, rent and care of meeting room, light, fuel, stenographer, and stereopticon operator services at meetings, etc.

At the end of each fiscal year the Treasurer of each Section and Division shall submit a certified copy of his accounts to the Secretary of the Association, the same being itemized and showing the balance on hand of funds received from the Association.

Section 5. The presiding officer of each Section and each Division shall be an Honorary Vice-President of the Association.

Section 6. Any Section may be dissolved by the Executive Committee for good and sufficient reasons.

Section 7. Two or more Local Sections may call or hold a regional meeting at such time and place as may be approved by the Executive Committee. The Executive Committee may authorize the Finance Committee to audit and approve, and the Treasurer to pay bills incurred to meet the expenses of holding such regional meetings. The amount to be paid not to exceed a sum fixed by the Executive Committee for each meeting. Bills shall be approved by the Section officer presiding at the regional meeting, before said bills are submitted to the Secretary for action by the Finance Committee.

ARTICLE XI

General

Section 1. Any member may, with the concurrence of the presiding officer, admit friends to the meetings of the Association, but such persons shall not take part in the discussions without the consent of the convention, and the privilege of the floor can only be granted to a non-member by unanimous consent.

Section 2. The Secretary shall send notice to all members of the Association at least fifteen days before the annual convention, giving the titles of papers to be read and mentioning any special business to be considered at said convention.

ARTICLE XII

Amendments

Section 1. All proposed amendments to the Constitution shall be submitted in writing to the Executive Committee which at its discretion may bring them before the next Annual Convention of the Association, but the Executive Committee must do so on the request in writing of five members of the Association.

Section 2. To pass an amendment to the Constitution, an affirmative vote of two-thirds of the members present and voting at said convention shall be required.

PAST PRESIDENTS

*Col. J. T. Foster, Chicago, Ill.	1881–1882
*Col. J. T. Foster, Chicago, Ill.	1882–1883
*J. G. Briggs, Terre Haute, Ind.	1883–1884
*L. H. Gardner, New Orleans, La.	1884–1885
*Peter Milne, Brooklyn, N. Y.	1885–1886
†B. F. Jones, Kansas City, Mo.	1886–1887
*J. T. Fanning, Minneapolis, Minn.	1887–1888
*A. N. Denman, Des Moines, Ia.	1888–1889
*J. H. Decker, Salina, Kans.	1889–1890
William B. Bull, Quincy, Ill.	1890–1891
*J. M. Diven, Elmira, N. Y.	1891–1892
*G. H. Benzenberg, Milwaukee, Wis.	1892–1893
James P. Donahue, Davenport, Ia.	1893–1894
*William Ryle, Paterson, N. J.	1894–1895
*W. G. Richards, Atlanta, Ga.	1895–1896
*F. A. W. Davis, Indianapolis, Ind.	1896–1897
John Caulfield, St. Paul, Minn.	1897–1898
*Joseph A. Bond, Wilmington, Del.	1898–1899
R. M. Clayton, Atlanta, Ga.	1899–1900
†C. E. Bolling, Richmond, Va.	1900–1901
*William R. Hill, New York, N. Y.	1901–1902
*C. H. Campbell, Charlotte, N. C.	1902–1903
†L. N. Case, Duluth, Minn.	1903–1904
Morris R. Sherrerd, Newark, N. J.	1904–1905
†Benjamin C. Adkins, St. Louis, Mo.	1905–1906
Dabney H. Maury, Peoria, Ill.	1906–1907
George H. Felix, Reading, Pa.	1907–1908
D. W. French, Weehawken, N. J.	1908–1909
Dr. William P. Mason, Troy, N. Y.	1909–1910
John W. Alvord, Chicago, Ill.	1910–1911
Alexander Milne, St. Catharines, Ont.	1911–1912
Dow R. Gwinn, Terre Haute, Ind.	1912–1913
Robert J. Thomas, Lowell, Mass.	1913–1914
George G. Earl, New Orleans, La.	1914–1915
Nicholas S. Hill, Jr., New York, N. Y.	1915–1916
*Leonard Metcalf, Boston, Mass.	1916–1917
Theodore A. Leisen, Detroit, Mich.	1917–1918
Charles R. Henderson, Davenport, Ia.	1918–1919
Carleton E. Davis, Philadelphia, Pa.	1919–1920
Beekman C. Little, Rochester, N. Y.	1920–1921
Edward Bartow, Iowa City, Ia.	1921–1922
W. S. Cramer, Lexington, Ky.	1922–1923
George W. Fuller, New York, N. Y.	1923–1924
Frank C. Jordan, Indianapolis, Ind.	1924–1925
Harry F. Huy, Buffalo, N. Y.	1925–1926
Allan W. Cuddeback, Paterson, N. J.	1926–1927

* Deceased.

† Not now a member of the Association.

CONVENTIONS

	Place	Date	President
1	St. Louis, Mo.	March 29, 1881	J. T. Foster
2	Columbus, Ohio	March 14–16, 1882	J. T. Foster
3	Buffalo, N. Y.	May 15–17, 1883	J. T. Foster
4	Cincinnati, Ohio	April 15–17, 1884	J. G. Briggs
5	Boston, Mass.	April 21–23, 1885	L. H. Gardner
6	Denver, Colo.	June 23–25, 1886	Peter Milne, Jr.
7	Minneapolis, Minn.	July 13–15, 1887	B. F. Jones
8	Cleveland, Ohio	April 17–19, 1888	J. T. Fanning
9	Louisville, Ky.	April 16–18, 1889	A. N. Denman
10	Chicago, Ill.	May 20–24, 1890	J. H. Decker
11	Philadelphia, Pa.	May 14–17, 1891	Wm. B. Bul
12	New York, N. Y.	May 17–19, 1892	J. M. Diven
13	Milwaukee, Wis.	September 5–9, 1893	G. H. Benzenberg
14	Minneapolis, Minn.	August 21–23, 1894	James P. Donahue
15	Atlanta, Ga.	May 28–30, 1895	William Ryle
16	Indianapolis, Ind.	May 26–28, 1896	W. G. Richards
17	Denver, Colo.	June 8–10, 1897	F. A. W. Davis
18	Buffalo, N. Y.	June 14–18, 1898	John Caulfield
19	Columbus, Ohio	May 16–19, 1899	Joseph A. Bond
20	Richmond, Va.	May 15–18, 1900	R. M. Clayton
21	New York, N. Y.	June 17–22, 1901	Charles E. Bolling
22	Chicago, Ill.	June 10–13, 1902	Wm. R. Hill
23	Detroit, Mich.	June 23–26, 1903	Chas. H. Campbell
24	St. Louis, Mo.	June 6–11, 1904	L. N. Case
25	West Baden, Ind.	May 9–12, 1905	Morris R. Sherrerd
26	Boston, Mass.	June 26–30, 1906	Benjamin C. Adkins
27	Toronto, Ont.	June 17–21, 1907	Dabney H. Maury
28	Washington, D. C.	May 11–16, 1908	George H. Felix
29	Milwaukee, Wis.	June 7–12, 1909	D. W. French
30	New Orleans, La.	April 25–29, 1910	Wm. P. Mason
31	Rochester, N. Y.	June 5–10, 1911	John W. Alvord
32	Louisville, Ky.	June 3–7, 1912	Alexander Milne
33	Minneapolis, Minn.	June 23–27, 1913	Dow R. Gwinn
34	Philadelphia, Pa.	May 11–15, 1914	Robert J. Thomas
35	Cincinnati, Ohio	May 10–14, 1915	George G. Earl
36	New York, N. Y.	June 5–9, 1916	Nicholas S. Hill, Jr.
37	Richmond, Va.	May 7–11, 1917	Leonard Metcalf
38	St. Louis, Mo.	May 13–17, 1918	Theodore A. Leisen
39	Buffalo, N. Y.	June 9–13, 1919	Charles R. Henderson
40	Montreal, Que.	June 21–25, 1920	Carleton E. Davis
41	Cleveland, Ohio	June 6–10, 1921	Beekman C. Little
42	Philadelphia, Pa.	May 15–19, 1922	Edward Bartow
43	Detroit, Mich.	June 21–25, 1923	W. S. Cramer
44	New York, N. Y.	May 19–23, 1924	George W. Fuller
45	Louisville, Ky.	April 27–May 1, 1925	Frank C. Jordan
46	Buffalo, N. Y.	June 7–11, 1926	Harry F. Huy
47	Chicago, Ill.	June 6–11, 1927	Allan W. Cuddeback

LIST OF OFFICERS 1927–1928

President

James E. Gibson, Manager and Engineer, Water Department, 14 George St., Charleston, S. C.

Vice-President

William W. Brush, Chief Engineer, Department of Water Supply, Gas and Electricity, Municipal Bldg., New York, N. Y.

Treasurer

George C. Gensheimer, Secretary, Commissioners of Water Works, Erie, Pa.

Secretary

Beekman C. Little, 305 Cutler Bldg., Rochester, N. Y.

Editor

Abel Wolman, 16 W. Saratoga Street, Baltimore, Md.

Trustees

Term Expiring 1928

R. L. Dobbin, Superintendent Water Works, 223 Aylmer St., Peterborough, Ont., Canada

George H. Fenkell, Superintendent and General Manager, Board of Water Commissioners, Jefferson & Randolph Sts., Detroit, Mich.

Patrick Gear, Superintendent Water Department, Holyoke, Mass.

Term Expiring 1929

Frederic E. Beck, Vice President and General Manager, Rochester & Lake Ontario Water Co., Powers Bldg., Rochester, N. Y.

J. O. Craig, Superintendent Water Works, Salisbury, N. C.

Theodore A. Leisen, General Manager, Metropolitan Utilities District, Utilities Bldg., Harney at 18th St., Omaha, Nebr.

Term Expiring 1930

Louis R. Howson, Alvord, Burdick & Howson, 130 Eighth Ave., La Grange, Ill.

George W. Pracy, Superintendent Spring Valley Water Co., 425 Mason St., San Francisco, Calif.

Seth M. Van Loan, Deputy Chief, Bureau of Water, 709 City Hall, Philadelphia, Pa.

Executive Committee

JAMES E. GIBSON, *Chairman*

GEORGE C. ANDREWS
FREDERIC E. BECK
WILLIAM W. BRUSH
J. O. CRAIG
ALLAN W. CUDDEBACK
R. L. DOBBIN
GEORGE H. FENKELL
PATRICK GEAR
GEORGE C. GENSHEIMER
LOUIS R. HOWSON
HARRY F. HUY
THEODORE A. LEISEN
BEEKMAN C. LITTLE
GEORGE W. PRACY
SETH M. VAN LOAN
ABEL WOLMAN

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Frederic E. Beck, Acting President, New York Section
Wellington Donaldson, Chairman, Water Purification Division
Mentor Hetzer, President, Central States Section
C. M. Grantham, President, North Carolina Section
G. C. Habermeyer, President, Illinois Section
John W. Hall, President, Montana Section
D. McLean Hanna, Chairman, Canadian Section
Nicholas S. Hill, Jr., Chairman, Fire Protection Division
John Kuester, Chairman, Wisconsin Section
J. W. McEvoy, Chairman, Iowa Section
W. E. MacDonald, Chairman, Plant Management and Operation Division
J. W. Moore, President, Indiana Section
Samuel B. Morris, Chairman, California Section
W. S. Patton, Chairman, Kentucky-Tennessee Section
G. C. Pruett, Chairman, Minnesota Section
Anson W. Squires, Chairman, Florida Section
Paul E. Strouse, Chairman, Rocky Mountain Section
Seth M. Van Loan, President, 4-States Section

AFFILIATED SOCIETIES

Kansas Water Works Association
Southeastern Water and Light Association

LIST OF COMMITTEES

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GEORGE C. GENSHEIMER, Secretary, Commissioners of Water Works, Erie, Pa.

GEORGE C. ANDREWS, 932 Ellicott Square Bldg., Buffalo, N. Y.

WILLIAM W. BRUSH, Chief Engineer, Department of Water Supply, Gas and Electricity, Municipal Bldg., New York, N. Y.

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ARTHUR E. GORMAN, Chief Sanitary Engineer, Dept. of Public Works, 6743 Olympia Ave., Chicago, Ill.

DANIEL C. GROBBEL, Assistant Secretary, Board of Water Commissioners, Detroit, Mich.

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JOHN F. LABOON, 346 Bowerhill Road, Pittsburgh, Pa.

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HOWARD E. MOSES, Assistant Chief Engineer, Penna. Dept. of Health, 904 N. 2nd St., Harrisburg, Pa.

ARTHUR L. MULLERGREN, Consulting Engineer, 770 Board of Trade Bldg., Kansas City, Mo.

W. S. PATTON, Manager, Ashland Water Works, Ashland, Ky.

RALPH W. REYNOLDS, Superintendent, West Palm Beach Water Co., Drawer B-25, West Palm Beach, Fla.

FINANCE COMMITTEE

GEORGE C. ANDREWS, Chairman, 932 Ellicott Square Bldg., Buffalo, N. Y.

CHARLES R. BETTES, Long Island Water Corp., Far Rockaway, L. I., N. Y.

E. G. WILHELM, Williamsport Water Co., Williamsport, Pa.

MEMBERSHIP COMMITTEE

A. U. Sanderson, Chairman, Toronto Filtration Plant, Foot of John St., Toronto, Ont., Canada.

Thomas L. Amiss, Superintendent Water and Sewage, Shreveport, La.

C. K. Calvert, Chemist, Indianapolis Sewage Commission, 1902 N. New Jersey Ave., Indianapolis, Ind.

CONVENTION COMMITTEE

Beekman C. Little, Chairman, 305 Cutler Bldg., Rochester, N. Y.

Malcolm Pirnie, Hazen and Whipple, 25 W. 43rd St., New York, N. Y.

V. Bernard Siems, Vice President and General Manager, North American Water Works Corp., 11 Broadway, New York, N. Y.

CONVENTION COMMITTEE OF WATER WORKS MANUFACTURERS ASSOCIATION

James H. Caldwell, 55 First St., Troy, N. Y.

John A. Kienle, Mathieson Alkali Works, 250 Park Ave., New York, N. Y.

Dennis F. O'Brien, A. P. Smith Manufacturing Co., East Orange, N. J.

DIVEN MEMORIAL COMMITTEE

Alexander Milne, Chairman, Superintendent Water Works, St. Catharines, Ont., Canada.

James M. Caird, Chemist and Bacteriologist, Cannon Bldg., Troy, N. Y.

James H. Caldwell, 55 First Street, Troy, N. Y.

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STANDARD SPECIFICATIONS FOR WATER METERS

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Seth M. Van Loan, Deputy Chief, Bureau of Water, 709 City Hall, Philadelphia, Pa.

STANDARD SPECIFICATIONS FOR HYDRANTS, VALVES AND SLUICE GATES

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FREDERIC E. BECK, Vice President and General Manager, Rochester & Lake Ontario Water Co., Powers Bldg., Rochester, N. Y.

JAMES H. CALDWELL, 55 First Street, Troy, N. Y.

DENNIS F. O'BRIEN, A. P. Smith Manufacturing Co., East Orange, N. J.

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STANDARD BRASS FITTINGS

WILLIAM R. EDWARDS, Chairman, Passaic Consolidated Water Co., 158 Ellison St., Paterson, N. J.

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STANDARD FORM OF CONTRACT

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REPRESENTATIVES OF A. W. W. A. ON AMERICAN ENGINEERING STANDARDS COMMITTEES

Standardization of Pipe Flanges and Fittings

FRANK A. BARBOUR, Hydraulic and Sanitary Engineer, 1120 Tremont Bldg. Boston, Mass.

Revision of Cast Iron Pipe Standards

FRANK A. BARBOUR, Hydraulic and Sanitary Engineer, 1120 Tremont Bldg., Boston, Mass.

Standardization of Fire Hose Coupling Thread

DENNIS F. O'BRIEN, A. P. Smith Manufacturing Co., East Orange, N. J.

Simplification and Standardization of Manhole Frames and Covers

FRANK A. MARSTON, 1300 Statler Bldg., Boston, Mass.

Specifications for Zinc Coating of Iron and Steel

RAY C. EWRY, Municipal Bldg., Room 2200, New York, N. Y.

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Committee No. 1—Standard Methods of Water Analysis

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Committee No. 2—Standards for Satisfactory Drinking Water—Work Completed.

Committee No. 3—Practicable Loadings for Purification Processes

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Richard Messer, State Dept. of Health, Richmond, Va.
E. H. Read, Johns Hopkins University, Baltimore, Md.
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Committee No. 4—Physical Chemistry in Relation to Water Purification—Work completed.

Committee No. 5—Watershed Protection—Work completed.

Committee No. 6—Industrial Wastes in Relation to Water Supply

Almon L. Fales, Chairman, 1300 Statler Bldg., Boston, Mass.
A. C. Decker, Tenn. Coal, Iron & R. R. Co., Birmingham, Ala.

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Committee No. 7—Pumping Station Betterments

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Committee No. 8—Physical Standards for Distribution System

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Committee No. 9—Standard Specifications for Cast Iron Pipe and Specials

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Committee No. 11—Sanitary Fountains—Work completed.

Committee No. 12—Testing of Water Works Materials and Supplies—Work completed.

Committee No. 13—Methods and Records of Water Waste Control—Work completed.

Committee No. 14—Committee on Meter Rates—Work completed.

Committee No. 15—Practical Standards of Rules and Regulations of Relations Between Water Works and Consumers—Work completed.

Committee No. 16—Essential Data for Water Records and Reports—Work completed.

Committee 17—Steel Pipe Lines—Work completed.

Committee No. 18—Filter Sand, Testing and Recording

Paul Hansen, Chairman, 6 No. Michigan Ave., Chicago, Ill.
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Committee No. 19—Boiler Feed Water Studies

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Committee No. 21—Specifications for Steel Standpipes and Water Towers

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List of Publications Abstracted

Affiliated Engineering Societies of Minnesota—Bulletin
American Chemical Society—Journal
American City
American Electro-Chemical Society—Proceedings
American Forestry
American Medical Association—Annual Index
American Medical Association—Journal
American Meteorological Society—Publications
American Public Health Association—Journal
American Railway Engineering Association—Journal
American Society of Civil Engineers—Proceedings
American Society for Municipal Improvements—Proceedings
Board of Fire Underwriters—Reports
Boston Society of Civil Engineers—Journal
Canada Department of the Interior—Water Supply Bulletins
Canadian Engineer
Canadian Water Works Association—Journal
City Reports (Misc.)
Cleveland Engineering Society—Journal
Concrete
Connecticut Association of Civil Engineers—Proceedings
Dayton Engineers' Club—Publications
Engineering Association of the South—Proceedings
Engineering and Contracting
Engineering News-Record
Engineers' Club of Philadelphia—Journal
Engineers of St. Louis—Journal
Engineers' Institute of Canada—Journal
Engineers' Society of Western Pennsylvania—Proceedings
Franklin Institute—Journal
Illinois Society of Engineers—Reports
Illinois State Water Survey—Bulletins
Indiana Engineering Societies—Proceedings
Ingenieria Internacional (Published in New York)
Iowa Engineering Societies—Proceedings

Journal of Bacteriology
Journal of Biological Chemistry
Louisiana Engineering Society—Proceedings
Mechanical Engineering (Jour. Am. Soc. M. E.)
Missouri Water Works Association—Journal
Monthly Weather Review (U. S. Weather Bureau)
Municipal and County Engineering
New England Water Works Association—Journal
Ohio Engineering Societies—Proceedings
Ohio Water Works Association—Proceedings
Pennsylvania Water Works Association—Proceedings
Power
Power Plant Engineering
Public Health Engineering Abstracts (U. S.)
Public Utility Reports
Public Works
Railway Age
Railway Maintenance Engineer
Railway Mechanical Engineer
Railway Review
Scientific Lubrication
Southwestern Water Works Association—Journal
State Boards of Health—Reports and Bulletins (Misc.)
U. S. Bureau of Agriculture—Bulletins and Circulars
U. S. Bureau of Census—Statistics
U. S. Bureau of Mines—Bulletins, Circulars and Technical Papers
U. S. Bureau of Standards—Bulletins, Circulars, Technical Papers, etc.
U. S. Dept. of Agriculture—Bulletins and Circulars
U. S. Public Health Service—Reports, Bulletins and Reprints
U. S. Geological Survey—Water Supply Papers, Bulletins and Circulars
University Bulletins (Misc.)
Utah Society of Engineers—Proceedings
Water Works Engineering
Western Society of Engineers—Journal

LIST OF MEMBERS

October 1, 1927

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Bull, William B. Quincy, Illinois	Apr. 30, 1925
Caulfield, John. 963 Linwood Place, St. Paul, Minn	July 14, 1887
Clayton, R. M. American Savings Bank, Atlanta, Ga	Apr. 5, 1891
Donahue, Col. James P. 520 Citizens Bank Bldg., Davenport, Ia	Apr. 16, 1884
Earl, George Goodell. Gen. Supt., 402 Sewerage & Water Bd. Bldg., New Orleans, La	July 18, 1907
Gwinn, Dow R. 215 Adams Bldg., Edgewood Grove, Terre Haute, Ind	Sept. 7, 1893
Herschel, Clemens. 2 Wall St., New York, N. Y	May 20, 1924
*Houston, Sir Alexander C. Director of Water Examinations, Metropolitan Water Board, 20 Nottingham Place, London, England	June 24, 1923
Keeler, H. E. The Rookery, Room 633, Chicago, Ill	July 14, 1887
*Mason, Dr. W. P. Professor of Chemistry, Rensselaer Polytechnic Institute, Troy, N. Y	May 18, 1892
Mulholland, William. Chief Engineer, Bureau of Water Works & Supply, Box 97, Los Angeles, Calif	June 24, 1923
Smith, J. Waldo. Consulting Engineer, Board of Water Supply, Municipal Building, New York, N. Y	July 15, 1898
Thomas, Robert J. 85–11th St., Lowell, Mass	May 16, 1900
Tighe, James L. Cons. Engr., 189 High St., Holyoke, Mass	Apr. 17, 1889

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Abbott, Carroll B. President, Water Works Supply Co., 536 Call Bdg., San Francisco, Calif	May 24, 1922
Abbott, G. H. Treas. and Supt., Southbridge Water Supply Co., Southbridge, Mass	May 17, 1912
*Absher, C. W. Supt. Filtration, Water & Light Dept., Mount Airy, N. C	Apr. 23, 1924
Ackerman, J. Walter. City Manager, Watertown, N. Y	Feb. 2, 1910
Acres, H. G. Pres., H. G. Acres & Co., Cons. Engrs. Main & Ferry Streets, Niagara Falls, Ont	June 6, 1927
Adams, Alton D. Box 88, Wellesley Hills, Mass	Sept. 30, 1912
Adams, C. M. Municipal Engineer, Obras Publicas, Santo Domingo, R. D	Apr. 23, 1927
Adams, Henry. Cons. Engr., 1263–69 Calvert Building, Baltimore, Md	Apr. 27, 1914
Aeryns, Albert Nelson, C.E. 716 Greenwood Ave., Brooklyn, N. Y	Jan. 18, 1915
Agar, E. W. Supt. Water Dept., Valparaiso, Ind	Mar. 16, 1927
Albin, W. W. Supt., Water Dept., San Diego, Calif	June 6, 1927

* Member of Water Purification Division

Alexander, R. C. Mgr., Water Co., Centerville, Iowa...... July 20, 1920
*Alfke, Charles J. Comptroller, Hackensack Water Company, 624 Park Ave., Weehawken, N. J. .... Mar. 23, 1925
*Alleman, Dr. Gellert. Prof. of Chemistry, Swarthmore, Pa. .... June 21, 1921
Allen, C. D. 50 Lombard St., Toronto, Ont., Canada...... Apr. 29, 1924
*Allen, Clayton M. Filter Operator, 111 West State St., Wellsville, N. Y. .... May 24, 1922
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Allen, Louis P. Superintendent of Construction, Consolidated Water Co., 712 Washington St., Utica, N. Y..... Dec. 13, 1926
Allen, S. L. Georgetown, Ky. .... Jan. 19, 1924
Allen, Thomas H. 1430 Bank of Commerce Bldg., Memphis, Tenn. .... Dec. 20, 1923
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Allin, T. D., C. E. 303 Kendall Bldg., Pasadena, Cal...... Mar. 28, 1910
Alpers, Frank H. Supt. Water Co., Cimarron, N. M. .... Oct. 14, 1919
*Alvord, John W. Cons. Engr., 1417-18 Hartford Bldg., Chicago, Ill. .... Apr. 3, 1899
Ames, Clarence F. Supt. Water Works, Norwich, N. Y..... Mar. 30, 1918
*Ames, Jeremiah L., 212 Sterling Ave., Buffalo, N. Y. .... Nov. 28, 1922
Amiss, Thomas L. Supt. Water and Sewerage, Shreveport, La. May 14, 1918
*Amsbary, F. C. Mgr. Water Co., Champaign, Ill. .... June 8, 1909
Anderson, A. L. Senior Civil Engineer, Construction Service, War Dept., Falls Church, Va. .... Nov. 10, 1925
Anderson, J. R. Supt. Water & Light, Rutherfordton, N. C. .... Dec. 29, 1924
Anderson, L. M. Controller, Dept. of Water Power, 207 S. Broadway, Los Angeles, Calif. .... Nov. 24, 1924
*Anderson, Robert M. Prof. Engineering Practice, Stevens Institute, Hoboken, N. J. .... Dec. 22, 1916
Andrews, George C. 932 Ellicott Sq. Bldg., Buffalo, N.Y.. Feb. 28, 1917
Andrews, Lewis P. Manager, Secy. and Treas. Water Co., Sedalia, Mo. .... Apr. 13, 1909
Andrews, Robert E. National Board Fire Underwriters, 1014 Merchants Exchange Bldg., San Francisco, Calif.. June 14, 1913
Angus, Robert W. Prof. of Mechanical Eng., University of Toronto, Toronto, Canada .... Feb. 5, 1917
Ankener, Richard. 140 12th Avenue, Long Island City, N.Y. .... Oct. 14, 1922
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Archer, Elmer T. Cons. Engr., New England Building, Kansas City, Mo. .... May 14, 1918
Archibald, J. G. Supt. Water Works System, Woodstock, Ont. .... Feb. 10, 1921
*Armstrong, James W. Filtn. Engr. City Water Dept., Lake Montebello, Hillen Road, Baltimore, Md. .... Mar. 12, 1910
*Armstrong, Kenneth C. Chemist, Water Dept., Florence Pump Station, Omaha, Nebr. .... Dec. 29, 1924
Armstrong, Roger W. 172 Clinton St., Brooklyn, N. Y.... Apr. 8, 1916
Arnold, Lloyd. 5834 Stoney Island Ave., Chicago, Ill...... Jan. 19, 1926
Atkinson, Asher. City Engr.. 49 Mine St., New Brunswick, N. J. .... Mar. 27, 1922
Attersall, Charles F. Supt., Water Works, Winchester, Ky. .... June 7, 1910

AUSTIN, R. N. Chf. Engr. & Mgr., Turbine Equipment Company, 73 King Street, West, Toronto, Canada....	May 12, 1925
AVERY, CHARLES NEEDHAM. Commissioner, Water, Light & Power, Austin, Texas....	May 28, 1924
AVERY, ELWOOD. Asst. Engr., Public Ser. Commission, 84 North 17th St., Harrisburg, Pa....	Feb. 28, 1922
AXE, EARL J. Chemist, Bureau of Water, 650 E. King St., Lancaster, Pa....	Apr. 26, 1926
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*BABBITT, HAROLD E. 204 Engineering Hall, Urbana, Ill.....	June 4, 1915
BABCOCK, G. H. Supt. Water Works, East Rochester, N. Y...	June 7, 1916
BACHARACH, E. W. Pres., E. W. Bacharach and Co., 616–17 Rialto Bldg., Kansas City, Mo....	Apr. 29, 1924
*BACHMANN, FRANK. Dorr Co., 310 So. Michigan Ave., Chicago, Ill....	Feb. 4, 1915
BADGER, H. F. Secretary, Board of Fire Und. of the Pacific, 914 Merchants Exchange Bldg., San Francisco, Calif..	Aug. 1, 1925
BADO, ATILIO A. Pueyrredon 1127, Buenos Aires, R. A.....	Nov. 6, 1924
*BAHLMAN, CLARENCE. Chief Bacteriologist Cincinnati Filtration Plant, California, Ohio....	Feb. 7, 1922
BAIN, ERNEST B. Supt., City Water Dept., Raleigh, N. C....	June 1, 1914
*BAITY, H. G. Assoc. Prof. School of Engineering University of N. C., Chapel Hill, N. C....	May 15, 1923
*BAKER, CLARENCE M. State Board of Health, Madison, Wis.	Oct. 4, 1915
BAKER, GERALD C. 208 Hanssler Place, Peoria, Ill....	Mar. 17, 1925
BAKER, HAROLD W. C. E., Comnr., Dept. of Public Works, Rochester, N. Y....	Jan. 31, 1922
BAKER, M. C. Supt. Water Dept., Jackson, Tenn....	June 6, 1927
*BAKER, M. N. Assoc. Editor, Engineering News-Record, 10th Ave. at 36th St., New York, N. Y....	June 24, 1903
*BALDWIN, F. O. Supt. Water Purification Plt., 2710 West Grace St., Richmond, Va....	May 10, 1922
*BALDWIN, HERBERT B., Chemist, Dept. of Health, 927 Broad St., Newark, N. J....	Mar. 27, 1919
*BALDWIN, ROBERT LEE. Cons. Engr. Burns & McDonnell, Engr. Co., 402 Interstate Bldg., Kansas City, Mo.....	Nov. 20, 1925
*BALDWIN, ROBERT T. Sect., Chlorine Institute, Inc., 52 E. 41st St., New York, N. Y....	July 28, 1924
BALL, EDMUND BRUCE. "Braemar" Ayr, Scotland....	Jan. 26, 1924
BALLARD, E. L. Engr., Underwriters Bureau of Middle & Southern States, 68 Beverly Road, Buffalo, N. Y......	June 17, 1926
BALLOU, ARTHUR FRANCIS. Engr. Natl. Board of Fire Underwriters, 85 John St., New York, N. Y....	Aug. 7, 1924
BANK, WILLIAM G. Asst. Engr., Bureau of Water, Newark, N. J....	Dec. 16, 1919
BANKS, HOWARD C. Supt. of Water Works, Wildwood, N. J.	May 11, 1927
*BANKSON, ELLIS E., C.E. 1111 Union Bank Bldg., Pittsburgh, Pa....	July 27, 1922
BANNISTER, H. W. Feedwaters, Inc., 40 Rector St., New York, N. Y....	Dec. 18, 1925
BANTEL, E. C. H. Prof. of Civil Eng., Univ. of Texas, 2307 San Antonio St., Austin, Texas....	Apr. 23, 1927
*BARBOUR, FRANK A. Hydraulic & Sanitary Engr., 1120 Tremont Bldg., Boston, Mass....	May 21, 1906
BARCLAY, HERBERT T. Superintendent Water Works, Water Department, City Hall, Kansas City, Kans....	July 22, 1926
BARCLAY, W. E. Supt. Dept. Water and Elect., Aurora, Ill...	May 13, 1918

BARDWELL, C. M. Assistant Water Engineer, Missouri-Kansas-Texas R. R. Co., 2609 Grim St., Waco, Texas..	July 6, 1926
*BARDWELL, R. C. 3211 Hanover Ave., Richmond, Va.....	Nov. 3, 1916
BARKER, J. R. Pacific Coast Manager, Neptune Meter Co., 320 Market St., San Francisco, Cal..................	June 15, 1926
BARNARD, W. K. 704 Central Bldg., Los Angeles, Calif......	Oct. 31, 1923
BARNES, CHAS. E. Secy. & Mgr., Elwood Water Co., Elwood, Ind...	Mar. 13, 1925
BARNES, HOWARD P. Div. Engr., Board of Water Sup. N. Y. C., Croton-on-Hudson, N. Y..........................	Mar. 15, 1924
BARNES, T. HOWARD. Cons. Engr., 1637 Whitehall Building, New York, N. Y....................................	Dec. 14, 1914
BARNES, W. V. Borough Engr., Dept. Water Supply, Gas & Elec., Borough Hall, Staten Island, N. Y.............	Feb. 26, 1926
BARNETT, A. G. 337 Fond du Lac St., Waupun, Wis.........	Apr. 30, 1923
BARNETT, C. P. Consulting Engineer, Covington, Virginia..	June 13, 1922
BARNHARD, P. Mgr., Mt. Carmel Public Utility Co., Mt. Carmel, Ill.......................................	Oct. 19, 1914
BARNS, FREDERICK B. Helling-Barns, Inc., 151 East 21st St., New York, N. Y....................................	Mar. 14, 1922
BARNUM, EDMUND KIRBY. Engr., Fresno City Water Corp., Fresno, Calif......................................	Mar. 31, 1925
*BARR, WILLIAM M. Consulting Chemist, Union Pacific Systems, Omaha, Neb..................................	Feb. 9, 1917
BARRICK, M. J. 1603 Junction St., South Williamsport, Pa..	Feb. 16, 1924
BARRIER, EDWARD A. Glen Road, Wellesley Farms, Mass..	June 24, 1924
BARSTOW, E. D. Barstow & McCurdy, Inc., 322 Ohio Bldg., Akron, Ohio..	Sept. 27, 1927
BARTLETT, N. EMORY. Natrona Water Co., 1000 Widener Building, Philadelphia, Pa............................	June 7, 1909
*BARTLETT, TERRELL. Cons. Engr., 612 Cacasieu Bldg., San Antonio, Tex.......................................	June 8, 1923
BARTLEY, ROBERT, Supt., Dept. Water & Sewers, Box 377, Asbury Park, N. J..................................	Mar. 8, 1924
*BARTOW, COL. EDWARD. Chemistry Dept., State Univ. of Iowa, Iowa City, Ia................................	June 7, 1909
BARTRAM, GEORGE C. 847 Ellicott Square Bldg., Buffalo, N. Y...	June 7, 1921
BARTUSKA, JAMES F. Supt. Water Dept., 288 Cleveland Ave., Whiting, Ind......................................	Oct. 14, 1924
BASOM, G. E. Supt., Water & Light Commission, Fairmont, Minn...	June 6, 1927
*BASS, FREDERICK H. 429 Union St., Minneapolis, Minn.....	Apr. 2, 1909
BASSETT, CARROL P., C.E. Summit, N. J.................	Oct. 14, 1909
BASSETT, CHARLES K., M.E., Buffalo Meter Co., 2917 Main St., Buffalo, N. Y...................................	June 13, 1921
BASSETT, GEO. B., C.E. 691 W. Ferry St., Buffalo, N. Y......	Apr. 12, 1909
BATCHELDER, GEORGE W. Water Commissioner, 19 City Hall, Worcester, Mass.....................................	Apr. 25, 1916
*BATES, CLINTON O. Analytical & Consulting Chemist, Cedar Rapids, Ia....................................	July 17, 1922
*BATES, RALPH D. State Dept. of Health, 23 S. Pearl St., Albany, N. Y.......................................	Feb. 10, 1921
*BATON, WARREN U. C. Chief Analyst, 528 S. Lang Ave., Pittsburgh, Pa....................................	Apr. 9, 1909
BATT, JOHN B. Supt. Water Works, North Tonawanda, N. Y.	Apr. 24, 1919
BAUDOUIN, OSCAR, C.E. 71A St. James Street, Montreal, Canada..	June 8, 1925
BAUEREISEN, R. J. 9 South Clinton St., Chicago, Ill.......	Aug. 8, 1915

BAYHA, CHAS. L. Superintendent Water Works, Box 536, Whitefish, Mont.	June 30, 1926
*BAYLIS, JOHN R. 6938 Crandon Ave., Chicago, Ill.	Oct. 2, 1915
BEAL, R. B. Chemist, The Flox Company, 117—27th Ave., S. E., Minneapolis, Minn.	June 6, 1927
BEAN, GEORGE L. Civil Engineer, 1729 N. 19th St., Philadelphia, Pa.	Dec. 29, 1913
BEARDSLEY, JOSEPH C. 1426 W. Third St., Rm. 303, Cleveland, Ohio	Apr. 15, 1909
BEASLEY, W. S. Agent, Dutchess Bleachery, Inc., Wappingers Falls, N. Y.	Jan. 7, 1927
BEAVERS, EDWARD HARMAN. Supt., Appalachian Power Company, Welch, W. Va.	Feb. 15, 1926
BECK, FREDERIC E. Vice President & General Mgr., Rochester & Lake Ont. Water Co., Powers Bldg., Rochester, N. Y.	Apr. 20, 1915
BECKER, CHARLES H. Mgr., Hydrant & Valve Department, R. D. Wood & Co., 400 Chestnut St., Philadelphia, Pa.	Aug. 25, 1927
BECKETT, RICHARD C. San. Engr., Delaware State Hlth. Dept., 205 N. State St., Dover, Del.	Sept. 27, 1924
BECKHAM, W. P. Superintendent of Water Works, Albemarle, N. C.	Aug. 28, 1926
BECRAFT, CARL A. City Hall, Miles City, Mont.	May 26, 1925
BEDELL, ARTHUR S. Elsmere, New York	June 10, 1920
BEDELL, JAMES. Supt., Water Works, 10 Croton Ave., Ossining, N. Y.	May 12, 1908
BEEBE, HARWOOD. Glenn Bldg., Spartanburg, S. C.	Dec. 8, 1923
BEECH, F. B. Gen. Supt., 101 Island Ave., McKees Rocks, Pa.	Jan. 5, 1925
*BEERS, WILLIAM H., Jr. Box 116, Gatun, Canal Zone	Sept. 12, 1922
BEESON, F. M. Mgr., Luitwieler Pumping Engine Co., 707 N. Main St., Los Angeles, Calif.	Oct. 27, 1925
*BEHRMAN, A. S. Chf. Chemist, International Filter Co., 333 W. 25th Pl., Chicago, Ill.	Feb. 28, 1925
BEISEL, N. J. Gen. Mgr., Pottsville Water Co., 221 S. Center St., Pottsville, Pa.	July 31, 1924
BELCHER, RICHARD. Prest. Water Co., Marysville, Cal.	Oct. 4, 1919
BELL, DAVID V. Supt., Water Companies, U. P. R R. Co., 408 So. Front St., Rock Springs, Wyo.	May 14, 1909
BELL, H. K. Civil Engr., 372 Transylvania Park, Lexington, Ky.	Jan. 16, 1924
BEMIS, EDWARD W. 332 S. Michigan St., Rm. 601, Chicago, Ill.	May 18, 1909
*BENHAM, WEBSTER L. Cons. Engr., 512 Gumbel Bldg., Kansas City, Mo.	June 9, 1919
BENTON, L. J. Supt. Water & Light Dept., Fremont, N. C.	Dec. 8, 1923
BERNHAGEN, LEWIS O. City Hall, Beaumont, Tex.	Mar. 6, 1917
BERRINO, JUAN B. Ingeniero Civil, Paraguay 3690, Buenos Aires, R. A.	Aug. 5, 1927
BERRY, ALBERT E. 31 Eighth Ave., Toronto, Ont., Can.	June 21, 1920
BERRY, F. R. Engr. Am. W. W. & E. Co., 50 Broad St., New York, N. Y.	Apr. 20, 1923
BERRY, FRED D. Sec. Bd. Water Comrs., Hartford, Conn.	Mar. 20, 1918
*BESSELIEVRE, E. B. Sanitary Engineer, Dorr Company, Inc., 247 Park Ave., New York, N. Y.	Oct. 7, 1919
BETTES, CHARLES R. Long Island Water Corp., Far Rockaway, L. I. N. Y.	June 18, 1901
*BEYER, ALBIN H., C.E. Assoc. Prof. in Civil Eng., Columbia University, New York, N. Y.	June 17, 1916
*BIGGS, GEORGE W., Jr. Chf. Engr. Amer. Water Works and Elect. Co., 50 Broad St., New York, N. Y.	June 2, 1916

*BILLINGS, LLOYD C. Supt. Filtn. Plant, 1247 Bemis St., S. E., Grand Rapids, Mich.	May 23, 1923
BIRD, BYRON. Municipal & Sanitary Engineer, 1602 Second Ave., North, Fort Dodge, Iowa	July 31, 1924
BIRD, CYRUS R. The Pitometer Co., 906 Majestic Bldg., Detroit, Mich.	Mar. 16, 1922
*BIRDSALL, LEWIS I. General Chemical Co., 300 W. Adams St., Box 3, Chicago, Ill.	June 24, 1913
BISER, D. BENTON. Asst. C. E., Water Dept. City Hall, Baltimore, Md.	Sept. 27, 1923
BISHOP, GUY H., C.E. Carolina Engineering Co., P. O. Box 1288, Charlotte, N. C	Sept. 26, 1921
BISHOP, WESLEY. Box 268, Warren Point, Bergen Co., N. Y.	Mar. 29, 1916
BLACK, ERNEST B. Cons. Engr., Mutual Building, Kansas City, Mo.	June 24, 1913
BLACK, GURDON G. 414 N. Union Blvd., St. Louis, Mo.	Feb. 13, 1915
BLACKWELDER, C. D. Post Box 266, Greenville, S. C.	May 18, 1926
BLAIN, CLAUD FRANCIS. Public Works Department, Sydney, N. S. W., Australia	Nov. 14, 1922
BLAIR, HOMER O. Equitable Bldg., Tacoma, Wash.	Aug. 17, 1925
BLAIR, McCREA PARKER. 1133 Catherine St., Victoria, West, B. C.	Apr. 20, 1910
BLAIR, T. J., JR. 16 S. Main Ave., Weston, W. Va.	Apr. 23, 1924
BLAISDELL, HIRAM W. Filtration Engineer, Maidstone Apartments, 1327 Spruce St., Philadelphia, Pa.	Sept. 24, 1925
BLAKEMAN, S. R. Supt., Water & Light Plant, Dyersburg, Ten.	Jan. 31, 1927
BLANCHARD, R. K., M.E. Engr., Neptune Meter Co., 50 East 42nd St., New York, N. Y.	June 19, 1919
BLATZ, WARREN D. General Sales Manager, Bridgeport Brass Co., Bridgeport, Conn.	Feb. 7, 1927
BLEISTEIN, BERNARD J. Asst. Engr., Dept. W. S., Gas & Elec., N. Y. C., 162 Lefferts Ave., Brooklyn, N. Y.	Apr. 26, 1918
BLESSED, WILLIAM S. Mech. Engr., 800 Marquette Bldg., Detroit, Mich.	June 1, 1923
BLEVINS, WILLIAM H. Mgr., Kentucky Utilities Co., Mt. Sterling, Ky.	Jan. 16, 1924
BLEW, MICHAEL JAMES. Research Engineer, Bureau of Engr., Department of Public Works, N. E. Dept., Richmond St. & Wheatsheaf Lane, Philadelphia, Pa.	Aug. 21, 1922
BLIVEN, CHARLES H. Supt. Norfolk City Water Dept., Norfolk, Va.	May 12, 1914
BLIVEN, GEO. H. Supt. Rochester and Lake Ont. Wtr. Co., 440 Powers Bldg., Rochester, N. Y.	Apr. 26, 1909
BLIVEN, JESSE A. Supt. New York Water Service Corp., 9002 91st Ave., Woodhaven, N. Y.	Mar. 24, 1926
BLIVEN, M. HARVEY. Water Works Engr., Eastman Kodak Co., 55 So. Washington St., Rochester, N. Y.	Apr. 12, 1921
*BLOHM, ARTHUR W. P. Asst. San. Engr. State Dept. of Health, 2206 Walbrook Ave., Baltimore, Md.	Aug. 9, 1922
*BLOMQUIST, H. F. Supt. City Water Works, Cedar Rapids, Ia.	May 13, 1917
BLOSSOM, FRANCIS. Engineer, 52 William St., New York, N. Y.	Apr. 9, 1906
*BOARDMAN, W. H. Civil Engr., 426 Walnut St., Philadelphia, Pa.	Apr. 18, 1909
BODKIN, J. T. St. Joseph Water Co., St. Joseph, Mo.	Mar. 19, 1924
*BOGERT, CLINTON L. Consulting Engineer, 30 Church St., Rm. 414, New York, N. Y.	Jan. 19, 1924

*BOHMANN, HENRY P. Supt. Water Works, Milwaukee, Wis. May 8, 1913
BOLTON, JAMES R. Supt. of Water Dept., City Hall, 20 Gerald Ave., Highland Park, Mich.......................... Mar. 25, 1924
BOOKER, WARREN H. 121 Crescent Ave., Charlotte, N. C... July 21, 1911
BOOTH, GEORGE W. 85 John St., New York, N. Y.......... Feb. 2, 1924
*BOOTH, L. M. Prest. Booth Chemical Co., P. O. Box 203, Elizabeth, N. J.................................... May 12, 1914
*BOOTH, WILLIAM MILLER. Cons. Chem. Engr., 526 University Bldg., Syracuse, N. Y.............................. June 8, 1909
BORDEN, MORO M. 310 Lees Ave., Collingswood, N. J........ June 5, 1912
*BORUFF, C. S. 801 E. First Ave., Monmouth, Ill,......... June 17, 1925
BOTTEN, H. H. Chief Engr., Washington Surv. & Rating Bur., P. O. Box 1818, Seattle, Wash........................ Jan. 16, 1924
BOVARD, PAUL F. Asst. Mgr., Sect. & Treas., California Filter Co., Inc., 618 Merchts. Exch., San Francisco.......... Aug. 12, 1926
*BOWE, THOMAS FRANCIS. Cons. Engr., 110 William St., New York, N. Y.. Feb. 9, 1920
BOWEN, EDWARD R. Reaburn & Bowen, Cons. Engineers, 1104 Central Bldg., Los Angeles, Calif................ July 20, 1925
BOWERS, H. S. Superintendent of Filtration, R. F. D., Denbigh, Va.. Aug. 28, 1926
BOWERS, HERBERT L. Chemical Engineer, Reiter Co., Elgin, Ill.. Oct. 13, 1926
BOWMAN, ABRAHAM M. Supt. Public Utilities, Elmira, Ont... Oct. 21, 1919
BOWNE, SIDNEY B. Civil Engineer, Mineola, N. Y.......... May 28, 1924
BOYCE, EARNEST. Chief Engineer & Director, Division of Water & Sewage, State Board of Health, Lawrence, Kans.. Apr. 13, 1926
BOYLE, BRYAN J. Wtr. Comnr. 2 Municipal Bldg., Buffalo, N. Y.. Mar. 16, 1922
BOYLE, EDWARD C. General Delivery, McAllen, Texas...... Apr. 12, 1916
BOYLES, MARVIN M. Engr., Water & Sewer Dept., City Hall, Greensboro, N. C.................................. Sept. 26, 1921
*BOYNTON, PERKINS. 624 Locust Ave., Clarksburg, W. Va... June 16, 1920
*BRADBURY, EDWARD GATLING. County Sanitary Engr., Court House, Columbus, O.......................... June 16, 1919
*BRADLEY, J. F. Chf. Engr. & Bact., R. F. D. 8, Valparaiso, Ind.. Feb. 10, 1921
BRAGG, GEORGE H. 445 Sutter St., San Francisco, Cal...... Oct. 14, 1922
BRAKENRIDGE, C. City Engineer, City Hall, Vancouver, B. C., Can.. Nov. 8, 1923
BRANDIS, FRED E. Supt., Municipal Water Works, Blaine Co., Chinook, Mont................................ Mar. 13, 1925
BRANTLY, E. C. Mgr., Water, Gas & Electric Depts., Danville, Va.. Feb. 21, 1927
BREEN, PETER J. Supt. Water Works Dept., Calgary, Alberta, Canada.. Mar. 16, 1927
*BREITZKE, CHARLES F. 412 William St., Boonton, N. J..... June 7, 1910
BRENNAN, DR. JAMES I. Managing Engr., Bureau of Water, 1600 Villanova Road, East Liberty, Pittsburgh, Pa.... Mar. 19, 1924
BRETZ, C. E. Supt. City Water Works, City Hall, Oklahoma City, Okla... Aug. 1, 1923
BREWER, GLENN. Superintendent, Atlantic Co. Water Co. of New Jersey, Pleasantville, N. J..................... Oct. 31, 1924
BRICKER, R. P. Pres., Shelby Water Co., Shelby, Ohio...... Nov. 19, 1915
BRIDGERS, J. H. Pres. Henderson Water Co., 123 N. Garnett St., Henderson, N. C................................ June 5, 1923
BRITAIN, WM. PERRY. Supt., City Water & Light Plant, West Plains, Mo... Nov. 12, 1926

Brockwell, Sherwood. Deputy, Ins. Comnr., Raleigh, N. C.	Nov. 18, 1921
Brooks, James E. Consulting Engineer, 40 Wildwood Terrace. Glen Ridge, N. J.	May 12, 1914
Brooks, John N. 339 Bellevue Ave, Trenton, N. J.	Feb. 24, 1912
Brooks, Thomas. Supt. Domestic Distribution, Water Department, 2045 N. Catalina St., Los Angeles, Calif.	Sept. 10, 1925
*Brossman, Charles. Cons. Engr., 1010 Chamber of Commerce Bldg., Indianapolis, Ind.	Apr. 7, 1916
Brower, I. C. City Manager, Lima, Ohio.	Apr. 18, 1915
Brown, C. Arthur. Sanitary Engineer, West Erie Ave., R. F. D. 2, Lorain, O.	June 27, 1905
Brown, C. D. Mgr. The Walkerville Water Co., Walkerville, Ontario, Can.	Oct. 16, 1916
Brown, Calvin S. The Belvedere, Toledo, Ohio.	Mar. 15, 1882
Brown, Prof. Charles Carroll, University Engr. Dept., Gainesville, Fla.	May 12, 1906
Brown, Edward. Supt. Water Works, Eau Claire, Wis.	Jan. 24, 1921
Brown, Horace A., C.E. Cons. Engr. and Supt. Water Works, Ottumwa, Iowa.	May 7, 1919
Brown, James. 425 East Olive St., Turlock, Calif.	Sept. 12, 1922
Brown, Kenneth W. Sanitary Engineer, California Water Service Co., Stockton, Calif.	July 11, 1927
Brown, Rasselas W. Supt. and Secty., Corry Water Supply Co., Corry, Pa.	Apr. 3, 1916
Browne, Floyd G. Supt. & Chemist, Sewage Treatment Works, 513 Delaware Ave., Marion, Ohio.	June 5, 1926
Brownell, R. E. Gen. Mgr., Palos Verdes Water Co., Palos Verdes Estates, Calif.	Nov. 15, 1926
Bruce, John A. Consulting Engineer, Bankers Reserve Life Bldg., Omaha, Nebr.	Oct. 21, 1920
Brush, Frederick Clinton. Mgr. Bound Brook Water Co., 519 Watchung Road, Bound Brook, N. J.	Jan. 7, 1924
*Brush, Wm. W. Chief Engineer, Dept. Water Supply, Gas and Electricity, Municipal Bldg., Rm. 2456, New York, N. Y.	Feb. 18, 1911
Buchanan, Albert Millar. Engr., Gartshore-Thomson Pipe & Fdy. Co. Ltd., Hamilton, Ont., Canada.	June 17, 1926
Buchanan, Edward Victor. Gen. Mgr., Public Utilities Comn., London, Ont., Canada.	Apr. 29, 1926
Buchanan, Hugh. Compania Consolidada de Aguas, Corrientes del Rosario, Ltda., Rosario de Santa Fe, A. R.	June 25, 1924
Buchanan, John H. Prof. Sanitary Chemistry, Iowa State College, Ames, Iowa.	May 26, 1927
Buck, George H. Asst. Engr., with Nicholas S. Hill, Jr., 55 Cherry St., Elizabeth, N. J.	Jan. 28, 1926
Buck, William H. Engr. and Supt. Construction, Riverton & Palmyra Water Co., Riverton, N. J.	May 7, 1916
Budd, Reid B. Asst. Supt. Trenton Water Dept., City Hall, Trenton, N. J.	Dec. 9, 1925
Buell, Wm. C. Gen. Mgr., Millville Water Co., High St., Millville, N. J.	June 17, 1926
Bugbee, Alvin. Supt. Trenton Water Dept., City Hall, Trenton, N. J.	Dec. 9, 1925
*Bugbee, Julius W. City Chemist, 290 Massachusetts Ave., Providence, R. I.	Feb. 20, 1924
Bughes, S. B. Superintendent Water Works, Reidsville, N. C.	Aug. 28, 1926
Buhrendorf, John C. C.E., 74 Fairview Ave., Yonkers, N. Y.	Mar. 25, 1924

Bull, Charles H. Asst. Engr., Dept. W. S. G. & E., 702 Madison Ave., New York, N. Y. ... Mar. 30, 1920
*Bull, Irving C. Analytical and Consulting Chemist, 50 West St., New York, N. Y. ... June 8, 1906
Bullard, J. L. Supt., Water, Light & Power Plant, Drawer 598, Lexington, N. C. ... Aug. 26, 1925
Bunker, George Cyrus. P. O. Box 5035, Ancon, C. Z. ... Feb. 23, 1911
Bunting, P. G. R. D. Wood & Co., Box 11, Petersburg, Va. Feb. 7, 1916
Burchard, Edwin Day. Dist. Engr., U. S. Geol. Survey, 316 Jackson Bldg., Asheville, N. C. ... Jan. 5, 1925
*Burdick, Charles B. Hydraulic and Sanitary Engr., 1417 Hartford Bldg., Chicago, Ill. ... July 18, 1907
Burgess, J. F. Pres. & Gen. Mgr., Montgomery Light, Water & Imp. Co., Box 338, Montgomery, W. Va. ... Dec. 29, 1924
*Burgess, Philip. Cons. Engr., 568 East Broad St., Columbus, Ohio ... Apr. 27, 1911
Burnett, Muscoe. Prest. Water Co., Paducah, Ky. ... June 22, 1923
Burnham, Harry A. Engr. & Sp. Insptr. F. M. F. Ins. Co., 68 Brookside Ave., Newtonville, Mass. ... June 16, 1920
Burnie, Arthur N. Vice President & Treasurer, Beaver Valley Water Co., 1006—7th Ave., Beaver Falls, Pa. ... Mar. 22, 1916
Burt, John. Gnl. Mgr. Marin Mcpl. Wtr. Works, 425 5th Ave., San Rafael, Cal. ... May 20, 1920
*Burt, L. B. National Lime Association, 927–15th St., N. W., Washington, D. C. ... July 31, 1924
*Buswell, A. M. Chief, State Water Survey Divn., Urbana, Ill. ... Mar. 20, 1916
Butler, F. W. W. Water Engineer's Dept., Durban, Natal, South Africa ... May 17, 1927
Butz, George W., Sr. 2301 Boulevard, Wilmington, Del. ... Nov. 20, 1923
Buzby, J. S. Box 310, Burlington, N. J. ... Sept. 30, 1919

Cadman, Robert M. Box 485, Red Bank, N. J. ... May 28, 1924
Caird, James M. Chemist & Bacteriologist, Cannon Bldg., Broadway & 2nd St., Troy, N. Y. ... May 16, 1900
Caldwell, James H., C.E. 55 First St., Troy, N. Y. ... July 10, 1906
Calhoun, J. W. Meter Foreman, New Chester Water Co., Box 264, Chester, Pa. ... May 14, 1921
*Calvert, Cecil K. Chemist, Indpls. Sewage Comn., 1902 N. New Jersey Ave., Indianapolis, Ind. ... Nov. 22, 1920
Cameron, Archibald Preston. c/o Worthington-Simpson, Ltd., Queens House, Kingsway, London, W. C. 2, Eng. June 4, 1912
Campbell, C. B. Supt., Bureau of Water, Altoona, Pa. ... May 10, 1915
*Campbell, Elmer W. State Dept. of Health, Augusta, Maine. Dec. 8, 1923
Campbell, George A. P. O. Box 2002, Reno, Nev. ... Apr. 9, 1913
Campbell, Myron G. Mgr. St. Albans Water & Ice Co., St. Albans, W. Va. ... Feb. 6, 1924
Campbell, Thomas. Water Purveyor, Town Hall, Kearny, N. J. ... June 17, 1926
Campion, Harry T. 142 Orchard Ave., Barberton, Ohio ... Nov. 30, 1920
Cannen, James V. Civil Engr., 1200 Hamilton Blvd., Hagerstown, Md. ... Mar. 27, 1925
Capron, John D. Statistical Engineer, U. S. Cast Iron Pipe & Fdy. Co., Burlington, N. J. ... Jan. 30, 1924
Carlin, Phil. Supt. Water Works, Sioux City, Iowa ... Apr. 14, 1891
Carpenter, Lewis V. Asst. Prof. Sanitary Engineering, West Virginia University, Box 562, Morgantown, W. Va. ... June 28, 1926
Carr, J. A. Supt., Water Dept., Ridgewood, N. J. ... May 3, 1916
Carrick, O. W. Wtr. Engr., Wabash Ry., 1636 E. William St., Decatur, Ill. ... Sept. 21, 1920

CARROLL, EUGENE. Vice Prest. and Mgr. Butte Water Co., Butte, Mont	June 7, 1904
CARSON, H. Y. Research Engineer, American Cast Iron Pipe Co., Birmingham, Ala	July 6, 1926
CASAD, CHARLES C. City Engineer & Supt. Water Dept., City Hall, Bremerton, Wash	Jan. 25, 1926
CASAD, ORLA. Superintendent Water Works, Box 624, Merced, Calif	Nov. 6, 1924
CASCADDEN, ALBERT. Supt. Power Plant, 1818½ Stone St., Port Huron, Mich	May 11, 1927
CASE, EGBERT D. Vice-Pres., Pitometer Co., 50 Church St., New York, N. Y	Mar. 4, 1921
CASE, H. R. Mgr. Corona City Water Co., 707 Main Street, Corona, Calif	May 28, 1926
CASGRAIN, CHARLES P. Mgr., Water Works, City Hall, Quebec, Canada	May 20, 1920
CATES, R. H. Pwr. Engr., So. Cal. Edison Co., P. O. Box 135, Los Angeles, Cal	June 16, 1920
*CATLETT, CAPT. GEORGE F. San. Engr., State Bd. of Hlth. Bureau of Eng. and Inspcn., Raleigh, N. C	June 7, 1919
CATON, F. E. Mgr. Water Dept., Princeton, Ind	June 6, 1927
CENTER, JOHN L. Superintendent Water Works, 64 Hypolita St., St. Augustine, Fla	Jan. 25, 1927
CHAMBERLAIN, L. H. 706 Wright & Callender Bldg., Los Angeles, Calif	Jan. 2, 1924
CHAMBERS, GEORGE H. Supt. Mntnce., B. of W., 50 Lake View Ave., Buffalo, N. Y	June 8, 1921
CHAMBERS, JOHN. Chief Engr. and Supt., Louisville Water Co., Louisville, Ky	June 8, 1921
*CHAMOT, E. M. Prof. Sanitary Chemistry, Cornell University, Ithaca, N. Y	Feb. 13, 1915
CHAMPE, GEORGE, C.E. 610 Nasby Building, Toledo, Ohio	Mar. 10, 1913
CHAMPION, ROY B. Supt. Public Works, 36 West 12th St., Holland, Mich	Mar. 11, 1914
CHAPMAN, F. W. Supt. Water Works, Camden, S. C	Dec. 5, 1925
CHAPMAN, WILLIAM J. Supt., Hudson Water Service Corp., 10 Maple Ave., Haverstraw, N. Y	Mar. 22, 1927
CHARTER, A. Supt., Municipal Light & Water Plant, Covington, Tenn	Sept. 18, 1926
CHASE, CHARLES P., C.E. 123 Sixth Ave., Clinton, Ia	Aug. 31, 1916
*CHASE, EDWARD SHERMAN. c/o Metcalf and Eddy, 1300 Statler Bldg., Boston, Mass,	May 3, 1919
CHASE, HORACE H. 610 West 146th St., New York, N. Y	May 28, 1924
CHASE, RICHARD D., C.E. 607 Purchase St., New Bedford, Mass	Nov. 3, 1919
CHENERY, CHRISTOPHER T. Pres., Federal Water Serv. Corp., 27 William St., New York, N. Y	June 17, 1926
CHERRY, B. F. Mgr., Weatherford Water, Light & Ice Co., Weatherford, Texas	Feb. 28, 1925
CHESTER, J. N., H. and M.E. Union Bank Building, Pittsburgh, Pa	Nov. 7, 1910
CHINN, KEITH R. P. O. Box 3113, West Palm Beach, Fla	Feb. 23, 1927
CHIPMAN, WILLIS, C.E. Mail Bldg., Toronto, Ont., Can	Apr. 18, 1888
CHISHAM, J. M. Supt. Water Co., Atchison, Kans	June 11, 1902
CHISHOLM, R. B. F. California Water Service Co., 401 San Joaquin Lt. & Power Bldg., Fresno, Calif	July 11, 1927
CHIVVIS, LELAND. 1437 McCausland Ave., St. Louis, Mo	Oct. 4, 1919
CHRISTENSEN, C. H. Mgr. Lt. & Water Co., Missoula, Mont.	Oct. 4, 1919
CHRISTMAN, C. H. Chemist, Bryson Hotel, Chicago, Ill	May 11, 1927

CHRISTY, J. F. Gen. Mgr., City Water & Light Plant, 411 Union St., Jonesboro, Ark.	Jan. 12, 1925
CLAFLIN, CHARLES R. Supt. Water Co., Rennselaer, N. Y.	Sept. 30, 1919
CLAIBORNE, HERBERT A. Contracting Engineer, 204 West Franklin St., Richmond, Va.	May 7, 1917
CLARK, A. E. Assoc. San. Engr., Department of Public Health, Tennessee Memorial Bldg., Nashville, Tenn.	June 10, 1919
CLARK, ARTHUR T. 42 Dundee Ave., Argyle Park, Babylon, N. Y.	May 16, 1919
CLARK, CHARLES M. 105 S. Division St., Peekskill, N. Y.	Apr. 4, 1924
CLARK, E. W. American Water Works & Elec. Co., 114 Carman Ave., Operating Dept., Lynbrook, L. I.	Mar. 8, 1924
CLARK, FREDK. W. G. Water Works Engr., British Municipal Council, Tientsin, N. China	June 22, 1923
CLARK, H. W. Prest. H. W. Clark Co., Mattoon, Ill.	May 29, 1895
*CLARK, HARRY W. Chf. Chmst., State Dpt. Hlth. Rm. 541, State House, Boston, Mass.	May 26, 1920
*CLARK, WILLIAM G. Cons. Engr., 1047 Spitzer Bldg., Toledo, Ohio	July 8, 1908
CLARK, WILLIAM H. Supt. Water Works, Avon, N. Y.	May 31, 1916
CLARKE, LEONARD. Distr. Mgr., Portland Elec. Pwr. Corp. 914 Main St., Vancouver, Wash.	Mar. 5, 1921
CLAYTON, NELSON J. Supt., Pottsville Water Co., 221 Centre St., Pottsville, Pa.	Mar. 27, 1925
CLEFLIN, EDWIN J. 50 Jefferson Ave., Jersey City, N. J.	May 28, 1924
CLEMENS, ALBERT. 303 Speed Building, Louisville, Ky.	Apr. 28, 1925
CLEMENS, O. E. Mgr., Wtr. Sales, S. V. Wtr. Co., 375 Sutter St., San Francisco, Cal.	Feb. 10, 1921
CLEVELAND, E. A. Chf. Comnr., Greater Vancouver Water Dist., 1303 Bekins Bldg., Vancouver, B. C., Canada	Mar. 12, 1924
CLEVELAND, H. BURDETT. Transportation Bldg., 225 Broadway, New York, N. Y.	Aug. 1, 1923
*CLEVERDON, WALTER S. L. Supervisor of Property & Assoc. Prof. of Sanitary Engineering, N. Y. Univ., Wash. Square, New York, N. Y.	Apr. 3, 1916
*CLIFTON, CHARLES ELMER. Chemist, Cannon Bldg., Troy, N. Y.	Mar. 12, 1910
CLOWES, JOHN HENRY. Specialist in W. W. Finance, 551 Fifth Ave., New York, N. Y.	June 15, 1927
COBURN, B. F. Superintendent Water Works, Robersonville, N. C.	Aug. 28, 1926
COBURN, JAMES W. Treasr. Rensselaer Water Co., P. O. Box 868, Portland, Me.	Feb. 19, 1923
COCHRAN, HORACE J. Pres., Maysville Water Co., Maysville, Ky.	May 28, 1924
COCHRAN, J. D. Supt. Water Works, Statesville, N. C.	Dec. 8, 1923
COFFEY, G. J. Pres., G. J. Coffey Co., 17th and Warren Sts., Wheeling, W. Va.	June 17, 1926
COFFIN, T. DEL. Asst. Engr., Bureau Water Supply City of N. Y., Katonah, N. Y.	Apr. 14, 1922
COLE, EDWARD S. Prest., The Pitometer Co., 50 Church St., New York, N. Y.	June 12, 1902
COLE, JOHN A. 1346 E. 53rd St., Chicago, Ill.	May 26, 1927
COLEMAN, JOS. L. Secy. & Supt., Citizens Water Company, P. O. Box 537, Deer Lodge, Mont.	Mar. 13, 1925
COLES, JOHN. Supt., Water Works, West York Township, 64 Earlsdale Yard, Toronto, 10, Canada	Mar. 16, 1927
COLLIER, F. E. Supt., Municipal Water Works, 253 Broad St., Cookeville, Tenn.	Apr. 13, 1926

Collins, A. Water Comnr., 981 Jepson St., Niagara Falls, Ont., Canada	June 8, 1921
Collins, W. D. Chemist, U. S. Geological Survey, Washington, D. C.	Dec. 18, 1925
Conard, W. R. Savings Institution Bldg., Burlington, N. J.	June 7, 1904
Connor, F. J. 221 No. Spring Ave., Sioux Falls, S. Dak.	May 16, 1900
Connor, Thomas J. Supt., Water & Light Dept., Gilbert, Minn.	June 2, 1920
Conrath, George A. Des Moines Water Works, Des Moines, Iowa	Aug. 18, 1925
Cook, John H. Hyd. Passaic Consol. Water Co., 158 Ellison St., Paterson, N. J.	July 10, 1906
Cook, Rodney E. 70 Lincoln Ave., Rockville Centre, L. I., N. Y.	Jan. 6, 1926
Cooke, J. R. Supt. Water Works, Franklinton, N. C.	Sept. 10, 1925
Cookingham, L. P. Village Manager, Village Hall, Clawson, Mich.	Feb. 18, 1927
Corbin, Clement K. Director Middlesex Water Co., 243 Washington St., Jersey City, N. J.	May 12, 1908
Corcoran, Harry J. Chf. Engr. Iowa Ins. Serv. Bur., 431 Ins. Exchg. Bldg., Des Moines, Iowa	Jan. 2, 1924
Corey, Ray Howard. Gnl. Mgr., Coos Bay Water Co., Marshfield, Ore.	June 19, 1920
*Corin, Magnus F. Chemist, 511 Hansberry St., Germantown, Pa.	Apr. 20, 1910
Corine, George A. Supt., Water & Gas Dept., Superior Water, Light & Power Co., Superior, Wis.	Oct. 31, 1924
*Corp, Charles I., Prof. Hyd. & San. Eng., Univ. of Wis., Madison, Wis.	Mar. 21, 1923
Cortese, J. R. Supt., Water Works, 411 So. Second St., Livingston, Mont.	Mar. 13, 1925
Cosculluela, Juan Antonio. Cons. Engr., O'Reilly y Mercaderes, Havana, Cuba	Oct. 16, 1913
*Coughlan, Robert E. Sprvsr. Wts. Sup. C. & N. W. Ry. Co., 4059 W. Monroe St., Chicago, Ill.	Feb. 28, 1923
*Coulter, Waldo S. Cons. Engr., 114 Liberty St., New York, N. Y.	Nov. 17, 1916
*Cousineau, Aime. City San. Engr., Health Dept., City Hall, Montreal, Canada	June 10, 1920
Cowan, P. H. Supt., Public Utilities, Galt, Ont., Canada	June 9, 1919
Cowles, M. Warren. Hackensack Water Co., Filtration Plant, New Milford, N. J.	Apr. 7, 1919
Cowles, Robert F. Engineer in Charge, Bureau of Water Development, 209 Pacific Bldg., San Diego, Cal.	Oct. 25, 1926
*Cox, Charles R. Asst. Engineer, State Department of Health, Albany, N. Y.	July 30, 1921
Cox, George W. Supt. of City Utilities, Harlan, Iowa	Oct. 31, 1923
Cox, Homer F. Chief Engr. Scranton Gas and W. Co., 430 Colfax Ave., Scranton, Pa.	May 12, 1914
Craig, Edward M., Jr. Apt. 51, 144 21st St., Jackson Heights, N. Y.	Oct. 11, 1923
Craig, J. O. Supt. Water Works, Salisbury, N. C.	May 24, 1922
*Craig, Robert Hall. Cons. Engr., 200 Telegraph Bldg., Harrisburg, Pa.	May 26, 1919
Cramer, Hugh R. Asst. Chf. Engr. Lexington Water Co., Lexington, Ky.	May 23, 1923
Cramer, W. S. Chf. Engr., Water Co., P. O. Box 42, Lexington, Ky.	May 12, 1908
Cranch, Eugene T. 156 Weyman Ave., New Rochelle, N. Y.	Mar. 19, 1922

Crane, Arthur M. P. O. Box 508, Hammond, Ind........ May 26, 1918
Crawford, Homer C. Prest. Centerville Water Co., Cooperstown, Pa........ June 6, 1919
Crawford, U. L. Engr. & Mgr., Tyrone Gas & Water Co., Tyrone, Pa........ Mar. 27, 1925
Crichton, Andrew B. Secty. and Trs., Portage Water Co., Johnstown, Pa........ May 29, 1915
Crockett, Harvey S. City Superintendent, 118 Schiller St., Elmhurst, Ill........ Jan. 26, 1924
Crofoot, E. H. Supt. City Water Works, Mason City, Iowa. Oct. 5, 1923
*Croft, H. P. Ch. Eng. State Dept. of Health, 208 Maple Ave., Trenton, N. J........ Jan. 7, 1924
Croll, Emiel A. Iron Mountain, Mich........ Sept. 7, 1893
Crow, J. W. Supt. of Water & Light, Municipal Bldg., Ponca City, Okla........ Feb. 23, 1924
Crowley, Cornelius M. Water Registrar, St. Paul, Minn... Oct. 18, 1918
Crozier, Ray. Engr. and Supt., Peoria Water Works, Peoria, Ill........ Feb. 5, 1915
Cruger, C. B. 2248 Nowland Ave., Indianapolis, Ind....... Nov. 15, 1924
Crum, Emory Clay. City Engineer, P. O. Box No. 354, Frederick, Md........ Feb. 13, 1924
Cuddeback, Allan W. V. P. and Treas. Passaic Consol. Water Co., 158 Ellison St., Paterson, N. J........ June 7, 1904
Culyer, Thurston C. 114 Goodrich St., Astoria, L. I., N. Y........ June 26, 1910
Cundiff, Stuart A. Supt. City Water Dept., Newport Beach, Calif........ May 24, 1927
Cunliffe, Russell W. Health Dept., City Hall, Milwaukee, Wis........ Dec. 13, 1926
Cunningham, F. G. c/o Fuller & McClintock, 170 Broadway, New York, N. Y........ Apr. 30, 1923
Cunningham, Joseph T. Supt., Flatbush Wtr. Wks. Co., 48 St. Pauls Place, Brooklyn, N. Y........ Nov. 25, 1921
Curd, P. B. Commissioner of Public Utilities, City Water Department, Wichita Falls, Texas........ May 12, 1925
Curran, James E. Supt., Water Bureau, 79 Linden St., Yonkers, N. Y........ Mar. 30, 1926
Currie, C. H. Cons. Engr., Webster City, Ia........ Apr. 20, 1920
Curtis, J. Eugene. Filtn. Plant, Washington, D. C........ May 3, 1923
Cutler, Leon G. 229 Satterthwaite Ave., Nutley, N. J..... Jan. 31, 1925
Cutts, Francis T. 306 Merchants-Laclede Bldg., St. Louis, Mo........ June 15, 1914

Daley, Freeman A. Supt., Municipal Water Dept., Newport Beach, Calif........ May 29, 1926
*Dallyn, F. A., C.E. 71 King St., W., Toronto, Ont., Can. Feb. 2, 1916
Damerow, Harry W. Supt., Light & Water Department, Vero Beach, Fla........ Dec. 22, 1926
Daniel, Frank R. Chief Engr., Wisconsin Inspec. Bureau, 490 Broadway, Milwaukee, Wis........ Aug. 18, 1924
*Daniels, Francis E. Eng. Div. State Dept. of Health, 2115 No. Second St., Harrisburg, Pa........ Sept. 2, 1916
Dappert, James W., C.E. Lock Box 141, Taylorville, Ill.... Oct. 23, 1914
Darby, W. Allen. San. Engr., The Dorr Company, 310 So. Michigan Ave., Chicago, Ill........ June 6, 1927
Darling, Ernest Howard, M.E. Consulting Engineer, 21 Stanley Ave., Hamilton, Ont., Canada........ Dec. 29, 1925
Darrow, Warren E. 314 Masonic Temple, Columbus, Ga.. Dec. 22, 1926
Davidson, George M. Ind. Engr., C. & N. W. Ry. Co., 226 W. Jackson Blvd., Chicago, Ill........ Mar. 11, 1915

Davies, Hugh. Master Mechanic, Hackensack Water Company, 624 Park Ave., Weehawken, N. J.	Mar. 13, 1925
Davis, A. A. Local Mgr., California Water Service Co., 606 Bird St., Oroville, Calif.	May 31, 1927
Davis, Arthur P. 505 Santa Ray Ave., Oakland, Calif.	Feb. 9, 1924
Davis, C. A. Superintendent Water Works, Box 748, Homestead, Fla.	Dec. 22, 1926
Davis, Carleton E. Manager, Phila. Suburban Water Co., 762 Lancaster Ave., Bryn Mawr, Pa.	Apr. 28, 1912
Davis, Frank J. Supt., Ansonia Water Co., 354 Main Street, Ansonia, Conn.	May 15, 1916
*Davis, H. F. Representing Wallace & Tiernan, c/o Charlotte Water Wks., Charlotte, N. C.	Dec. 8, 1923
Davis, P. D. Asst. Engr., c/o Wm. M. Piatt, Durham, N. C.	Jan. 12, 1922
Davis, W. L. Supt., Water Dept., P. O. Box 266, Portsmouth, Va.	July 8, 1922
Daw, Lawrence. Chf. Engr., Underwriters Assn. of N. Y., 700 Gurney Building, Syracuse, N. Y.	May 9, 1916
Day, Leonard A. Water Commissioner, 312 City Hall, St. Louis, Mo.	Apr. 24, 1917
Dean, John M. Water Commissioner, First Natl. Bank Bldg., Memphis, Tenn.	June 6, 1927
Dean, Silas S. Mechanical Engineer, Aurora, Ill.	June 6, 1927
DeBerard, W. W. Chf. Engr., Regional Planning Assn., 160 N. La Salle St., Chicago, Ill.	June 3, 1912
De Brito, F. Saturnino R. Consulting Engineer, Caixa Postal 1631, Rio de Janeiro, Brazil	Jan. 25, 1926
*Decker, A. Clinton. Sanitary Engr., Tenn. Coal, Iron & Railroad Co., Birmingham, Ala.	June 2, 1914
*Decker, Arthur J. Consulting Civil Engr., 2014 Geddes Ave., Ann Arbor, Mich.	May 23, 1923
DeCosta, Joseph D. 1509 Albany Terrace, Albany, Calif.	Sept. 17, 1923
De Horatiis, Manfredi. R. Instituto Forestale, Firenze, Italy	Apr. 30, 1926
Delaney, J. T. Supt. City Water Works, Los Banos, Calif.	Oct. 14, 1924
*Delaporte, A. V. Chemist in Charge, Experimental Sta., Clifford St., Dept. of Health of Ontario, Toronto, Ont., Canada	Mar. 27, 1925
DeLeuw, Charles E. Kelker, DeLeuw & Co., Engrs., 111 W. Washington St., Chicago, Ill.	Nov. 30, 1923
DeMartini, Frank Edward, Sanitary Engineer, 637 Greenwich St., San Francisco, Calif.	Sept. 13, 1927
DeMoya, P. Paul. Mgr., Consumers Water Co., Stuart, Fla.	Dec. 22, 1926
Denman, Charles Sing. Genl. Mgr. Des Moines Water Co., Des Moines, Iowa	Dec. 10, 1915
Dennett, Robert C. Hyd. Engr., c/o Natl. Board Fire Underwriters, 85 John St., New York, N. Y.	May 15, 1914
Derby, R. L. San. Engr., Salisbury, Bradshaw & Taylor, 743 Petroleum Securities Bldg., Los Angeles, Calif.	May 29, 1926
Detwiler, L. F. Supt., Goldfield Consol. Water Co., Goldfield, Nevada	June 28, 1924
Devaughn, Okey H. Supt. Dept. of Water Works & Sewers, 1440—7th St., Parkersburg, W. Va.	Sept. 22, 1925
*Devendorf, Earl. Asst. San. Engr. St. Dept. of Hlth., 1239 Albany St., Schenectady, N. Y.	May 22, 1919
Devilbiss, H. Roland. Dept. Engr., Washington Suburban Sanitary Dist., Hyattsville, Md.	Apr. 10, 1922
Dewey, Chester R. Vice Pres., Consolidated Water Co. of Utica, First National Bank Building, Utica, N. Y.	Jan. 19, 1926

Di Domenico, Anthony F. 727 Aisquith St., Baltimore, Md.	Mar. 9, 1927
Diehl, George C. Cons. Engr., 577 Elicott Square, Buffalo, N. Y.	May 15, 1923
Dienert, M. 6 Rue de Seine, Paris VI, France	Feb. 28, 1925
Diggs, Franklin, Jr. San. Engr., Linthicum Heights, Md.	Sept. 11, 1923
*Diggs, John C. San. Engr., Department of Conservation, 126 State Capitol, Indianapolis, Ind.	Sept. 9, 1919
*Dignan, B. T. Chem. and Bact., City Water Works, Niagara Falls, N. Y.	Apr. 10, 1919
Dill, H. A. Supt., Water Works, Richmond, Ind.	May 16, 1900
Diller, J. W. Superintendent, Water Works, Wilber, Nebr.	July 31, 1924
Dillon, S. E. Local Mgr., California Water Service Co., Box 1148, Bakersfield, Calif.	May 31, 1927
Dish, Edward. Gamon Meter Co., 922 Milton Ave., South Bend, Ind.	Feb. 7, 1925
Dittoe, W. H. Chief Engineer, Mahoning Valley Sanitary District, Youngstown, Ohio	May 28, 1914
Diven John M., Jr. The Leadite Company, Inc., Land Title Bldg., Philadelphia, Pa.	June 17, 1913
Dixon, Frederic John. Chf. Engr. Staffordshire Wtr. Wks., 264 Paradise St., Birmingham, England	Aug. 8, 1919
Dixon, G. Gale. Office Engineer, The Mahoning Valley Sanitary District, 901 City Bank Bldg., Youngstown, Ohio	June 21, 1920
Dixon, Jas. I. Superintendent Water Dept., 401 Benton St., Santa Clara, Calif.	May 14, 1926
Dobbin, R. L. Supt. Water Works, 223 Aylmer St., Peterborough, Ont., Can.	Feb. 28, 1923
*Dodd, Rennie I. Federal Water Service Corp., 27 William St., New York, N. Y.	Apr. 10, 1922
Dodge, Fred L. Asst. Mgr., Belvedere Water Corp., 4163 Whittier Blvd., Los Angeles, Calif.	July 22, 1926
Domogalla, Dr. Bernhard. Chemist, University Club, 803 State St., Madison, Wisc.	Feb. 17, 1926
*Donaldson, Wellington. c/o Messrs. Fuller & McClintock, 170 Broadway, New York, N. Y.	Apr. 29, 1910
Dones, J. W. Asst. Supt. & Engineer, City Water Department, Tulsa, Okla.	June 6, 1927
*Donnelly, R. V. Pres., The Paradon Mfg. Co., 573 Elm St., Arlington, N. J.	Apr. 7, 1917
Donohue, Jerry. Prest., Donohue Engineering Co., Sheboygan, Wis.	June 20, 1922
Dorrance, Frank Young. Divn. Engr., Montreal Water Bd., 341 Brock Ave., North, Montreal West, P. Q., Can.,	July 14, 1920
Dorsey, Stanton L. Sanitary Engineer, Room 790, Arlington Bldg., Washington, D. C.	May 28, 1924
Doten, Capt. Leonard S. 2318 Kaala Ave., Honolulu, T. H.	Aug. 19, 1914
Dougherty, Ben R. Supt., Richmond Water & Light Co., Richmond, Ky.	Apr. 16, 1924
Dougherty, D. J. Mgr. & Supt., P. O. Box 418, Talladega, Ala.	May 12, 1925
Dougherty, Robert E. P. O. Box A-43, West Palm Beach, Fla.	Feb. 7, 1922
Douglass, Robert M., C. E. 912 Columbia Bank Bldg., Pittsburgh, Penn.	May 12, 1923
Dow, Alex. 2000 Second Ave., Detroit, Mich.	Aug. 4, 1919
Dowd, John E. 162 85th St., Brooklyn, N. Y.	Mar. 4, 1922
Dowling, F. F. Chief Engineer, British Columbia Fire Undwtrs., 1021 Rogers Bldg., Vancouver, B. C., Canada	May 31, 1924

DOWNER, T. B. Chf. Engr. & Supt., Alhambra Water Dept., 210 South Fifth Street, Alhambra, Calif.	Apr. 9, 1925
DOWNES, JOHN R. Green Brook Park, Bound Brook, N. J.	July 10, 1906
*DRAKE, CHESTER F. Div. Supt., Pittsburgh Filtration Plant, Aspinwall, Pa.	Apr. 27, 1910
DRAKE, EDWARD. New Bedford, Mass.	Jan. 29, 1921
DRAKE, WILLIAM O. City Engr., Supt. Public Works, City Hall, Corning, N. Y.	Apr. 30, 1917
DRANE, BRENT S. Consulting Engineer, 19 W. 4th St., Charlotte, N. C.	June 28, 1924
DRAPER, OSCAR C. Water Commissioner, N. W. Cor. 7th & Jackson Sts., Wilmington, Dela.	Jan. 27, 1926
DROW, F. O. 1103 Superior Avenue, Tomah, Wis.	May 29, 1925
DRUAR, JOHN F. Cons. Engr., 500–504 Globe Bldg., St. Paul, Minn.	Nov. 18, 1919
DRYDEN, FRANCIS H. City Engineer, Salisbury, Md.	May 13, 1924
DUANE, LOUIS V. Superintendent of Water Works, City Utilities, Sanford, Fla.	Aug. 19 1926
DUFFY, JAMES M. Village Engineer, Mamaroneck, N. Y.	June 6, 1922
*DUGGAN, THOMAS R., PH.D., F.I.C. Chemists Club, 52 East 41st St., New York, N. Y.	Dec. 9, 1913
DUGGER, EUGENE F. Gen. Mgr., Newport News Waterworks Comn., Newport News, Va.	May 17, 1924
DUMOULIN, W. L. Gnl. Supt., New Cornelia Copper Co., Ajo, Arizona	June 18, 1910
*DUNHAM, H. F., C.E. 32 West 40th St., New York, N. Y.	Apr. 16, 1884
DUNHAM, HENRY G. 920 Henry Street, Detroit, Mich.	June 16, 1925
DUNLAP, FRED C. 6621 No. 12th St., Philadelphia, Pa.	May 12, 1908
*DUNN, WM. CAREY. Supt. Mt. Hope Filter Plant, Box 541, Cristobal, C. Z.	Nov. 12, 1919
*DUNWOODY, J. S. Supt., Water Department, Erie, Pa.	June 5, 1913
*DURBIN, W. H., C.E. Asst. Mgr. T. H. Water Works Co., 634 Cherry St., Terre Haute, Ind.	May 23, 1923
DURLAND, SMITH N. Cashier, Long Island Water Corp., 15 John St., Far Rockaway, N. Y.	Jan. 29, 1914
DWYER, CORNELIUS. 18 Chuctanunda St., Amsterdam, N. Y.	Apr. 11, 1914
DWYER, JOHN D. Chairman, Water & Sewer Board, 228 Spring St., Medford, Mass.	May 24, 1922
DYHRKOPP, F. G. Mgr., Dyhrkopp Engineering Co., 222½ South Illinois Ave., Carbondale, Ill.	Nov. 18, 1925
EAGAN, OWEN J. Water Commissioner, Somerset, Mass.	June 6, 1927
*EARL, RALPH. Hyd. Engr., Sewerage and Water Board, Water Purification Dept., New Orleans, La.	June 6, 1916
*EASBY, WILLIAM, JR. Civil & Sanitary Engr., 1201 Chestnut St., Philadelphia, Pa.	Mar. 12, 1924
EASTERDAY, E. E. Assistant Division Engineer, Supply & Purifying Sec., Water Div., 4539 Arco Ave., St. Louis, Mo.	May 29, 1926
EASTWOOD, CHARLES H. San. Engr., Bureau of Engineering, Fla. State Board of Health, Jacksonville, Fla.	May 28, 1926
EASTWOOD, JOHN THOMPSON. Prin. Asst. Engr., Sewer & Water Bd., City Hall Annex, New Orleans, La.	May 24, 1909
EBELER, CHARLES J. Supt. of Distribution, Water Dept., 4600 McRee Ave., St. Louis, Mo.	May 17, 1927
EDDY, HARRISON P. Metcalf & Eddy, 1300 Statler Bldg., Boston, Mass.	May 20, 1925
EDDY, JUSTUS B. Engineer, Water Pipe Extension, 404 City Hall, Chicago, Ill.	June 21, 1926

Edwards, William R. Supt. Passaic Consol. Water Co., 158 Ellison St., Paterson, N. J.	Apr. 2, 1914
Eginton, James T. Supt. Cortland Water Dept., 23 Court Street, Cortland, N. Y.	Apr. 10, 1926
Ehle, Chester G. Chf. Dftsmn. & Distbn. Engr. Wtr. Bureau, 211 City Hall, Portland, Ore.	Mar. 21, 1923
Ehrhart, C. L. City Manager, Clarinda, Iowa	Apr. 30, 1919
Eldridge, H. D. Treas., Princeton Water Co., Princeton, N. J.	Apr. 14, 1916
Ellefson, C. O. Lock Drawer "E," Proctor, Minn.	May 24, 1927
Elliott, G. A. Chf. Engr., Spring Valley Water Co., 425 Mason St., San Francisco, Calif.	May 15, 1918
Ellis, George R. Canandaigua, N. Y.	July 18, 1907
Ellis, Herbert C. 201 Forest Ave., E., Detroit, Mich.	July 27, 1926
Ellis, Luke. Serv. Engr., Pub. Serv. Comm. of Md., 1722 Munsey Bldg., Baltimore, Md.	Sept. 23, 1924
Ellis, N. Randall. Valtn. Engr. City Atty. Office, 453 City Hall, San Francisco, Calif.	June 9, 1920
Ellms, Joseph W. 1310 West 112th Street, Cleveland, Ohio.	Oct. 21, 1919
Ellsworth, Harry. Supt. Water and Light Dept., Meadville, Pa.	July 18, 1907
Elrod, Henry E. Hills Fraser Bldg., Room 216, Santa Monica, California	Feb. 2, 1916
Elsberg, N. W. City Engr., 203 City Hall, Minneapolis, Minn.	May 23, 1923
*Ely, Howard M. Superintendent Water Co., Danville, Ill.	June 8, 1909
Ely, John S. Division Engineer, Div. of Water, Room B3, City Hall, Newark, N. J.	Mar. 20, 1922
Emerson, C. A., Jr. 804 Pennsylvania Bldg., 15th & Chestnut Sts., Philadelphia, Pa.	May 12, 1908
Emerson, Frank. Engr. & Supt. of Public Wks., Melrose, Mass.	Nov. 12, 1919
Emparan, R. R. Manager, Sonoma Water & Irrigation Co., Sonoma, Calif.	June 15, 1926
Enander, E. H. Engr., Distr. Public Service Co. of Northern Ill., 75 W. Adams St., Chicago, Ill.	June 27, 1922
End, William F. Civil Engineer, 360 Third St., Troy, N. Y.	Jan. 19, 1926
Engel, P. N. 333 W. 25th Place, Chicago, Ill.	June 12, 1919
Enger, M. L. Prof. Mechanics and Hydraulics, Univ. of Ill., Urbana, Ill.	Mar. 11, 1915
Engh, Harry M. Manager, Public Utilities Dept., The American Appraisal Co., Milwaukee, Wis.	Mar. 25, 1916
England, R. G., C.E. Fargo Engineering Co., 147 So. Mechanic St., Jackson, Mich.	Sept. 2, 1914
Engle, James W. Big Bethel Water Development, R. F. D. No. 2, Box 110, Hampton, Va.	Sept. 4, 1923
Ennis, Harry W. City Engineer, City Hall, Bowling Green, Ky.	Oct. 20, 1926
*Enslow, L. H. c/o The Chlorine Institute, Inc., 30 East 42nd St., New York, N. Y.	Aug. 16, 1918
Enzweiler, Robert A. Paintsville, Ky.	Jan. 19, 1926
Eppich, Karl E. Engineer, Mountain States Inspection Bureau, P. O. Box 1740, Denver, Colo.	Mar. 3, 1927
Erickson, Charles A. Supt. of Water Works, 622 East Main St., Sparta, Wis.	July 30, 1925
Erickson, D. L. City Engineer, Lincoln, Nebr.	June 30, 1924
*Erickson, Wendell J. Asst. Sanitarian, State Dept. of Health, 1552 Nott St., Schenectady, N. Y.	Jan. 19, 1924

Ervast, Andrew. Mgr., Coronado Water Co., 440 Union Bldg., San Diego, Calif. .... Oct. 11, 1923
Esty, Roger W. Supt., 17 Hobart St., Danvers, Mass. .... Mar. 1, 1924
Etnyre, S. L. 302 No. 2nd St., Council Bluffs, Iowa .... May 10, 1915
*Etzel, George C. Analyst, 1101 12th Ave., Rock Island, Ill. .... June 5, 1916
Evans, Alfred W. 160 Knowlton Avenue, Kenmore, N. Y. .... Apr. 27, 1925
Evans, Charles. Supt. of Constr., 540 Haller St., Lima, O. May 26, 1923
Evans, Edmund Boyce. Asst. Bacteriologist, Water Works, 1215 Elgin Pl., Mt. Adams, Cincinnati, Ohio .... Jan. 27, 1927
*Everett, Chester M. Hazen and Whipple, 25 W. 43rd St., New York, N. Y. .... May 10, 1915
Everett, Jasper W. Supt., Penobscot Co. Wtr. Co., Orono, Me. .... May 5, 1922
Everette, Willis Eugenes. P. O. Box 188, San Rafael, Calif. .... Dec. 29, 1913
*Evers, Hubert J. Chemist & Bacteriologist, 1321 Pennsylvania Ave., E. St. Louis, Ill. .... Mar. 13, 1925
Ewing, James. Hunter Dist. Water Sup. and Sew. Bd., Newcastle, N. S. W., Australia .... Nov. 5, 1913
Ewry, Ray C. Municipal Bldg., Rm. 2200, New York, N. Y. .... Apr. 4, 1924
Eymer, Herman H. City Engineer, Saginaw, Mich. .... June 4, 1912

*Fager, E. P. Chst. & Bct. Dearborn Chem. Co., 1029 W. 35th St., Chicago, Ill. .... Aug. 5, 1920
Fair, Al. Commissioner, Water Dept., Casper, Wyo. .... Jan. 14, 1927
*Fair, Gordon Maskew. Instructor in San. Engineering, Harvard University, 112 Pierce Hall, Cambridge, Mass. .... Jan. 26, 1925
Faitoute, Frederic B. Civil Engr. & Water Works Supt., 138 Sayre Street, Elizabeth, N. J. .... Aug. 11, 1927
*Fales, Almon L. Metcalf & Eddy, 1300 Statler Bldg., Boston, Mass. .... Feb. 26, 1921
Farmer, Ollef O. 511 Manchester Ter., Inglewood, Calif. .... Nov. 8, 1923
Farquharson, Alex. L. Mgr. Brockville Public Utilities Victoria Hall, Brockville, Ont., Can. .... Mar. 8, 1924
Farrar, H. L. Dist. Mgr., Southern Illinois Gas Co., Murphysboro, Ill. .... Oct. 21, 1920
Farrell, James W. D. Supt. Water Works, 3035 Rae St., Regina, Sask., Can. .... Feb. 23, 1920
Farrell, L. L. Supt. East Bay Water Co., 512 Sixteenth St., Oakland, Calif. .... Sept. 21, 1922
Farrell, Thomas S. 1054 Kenneth Dr., Rocky River Br., Cleveland, Ohio .... June 7, 1921
Fasoli, P. Supt. Springbrook Water Co., Hudson Falls, N. Y. .... July 12, 1922
Feeney, A. J. Asst. Engr. & Supt. Water Dept., Wilmington, Del. .... Apr. 30, 1919
Feeter, Silas S. City Engr. & Supt. Water Works, Little Falls, N. Y. .... Oct. 22, 1921
Feist, Martin. Supt. Mch. Eqpt. St. P. Wtr. Wks., Dayton's Bluff Stn., B. 4, St. Paul, Minn. .... May 13, 1919
Felix, George H. 138 N. Ninth St., Reading, Pa. .... Sept. 7, 1893
Fenkell, George H. Supt. and Gnl. Mgr. Bd. Wtr. Comnrs., Jefferson and Randolph Sts., Detroit, Mich. .... June 21, 1920
Ferguson, Emery E. North American Water Works Corp., 11 Broadway, New York, N. Y. .... Apr. 10, 1922

*Ferguson, G. H., B.A.Sc. Chief Engr., Dept. of Health, Elgin Building, Ottawa, Canada........ Mar. 19, 1925
*Ferguson, Harry Foster. Chf. Eng., State Dept. of Hlth., Springfield, Ill........ Nov. 9, 1914
Ferguson, John B., C.E. Hagerstown, Md........ Sept. 30, 1919
Ferris, T. E. Chrmn. Wtr. Comnrs., Niagara Falls, Ont., Can. Feb. 10, 1921
Fewell, J. H. Superintendent, Water Dept., Jackson Miss........ June 17, 1926
*Field, Frederick E. Engr. Water Bd., 135 Ballantyne Ave., Montreal, West, P. Q., Can........ June 21, 1920
Field, William T. Consulting Engineer, Flower Bldg., Watertown, N. Y........ Apr. 27, 1910
Fields, F. V. Supt., Water & Light Dept., Mooresville, N. C. Apr. 23, 1924
Fifield, Gilbert H. Asst. Engr., Board of Water Supply N. Y. C., Prattsville, N. Y........ Mar. 19, 1924
Filby, E. L. Chf. San. Engr., State Board of Health, Jacksonville, Fla........ Feb. 7, 1922
Finch, J. D. Superintendent of Water Works, Box 76, Zebulon, N. C........ Aug. 28, 1926
Finch, Ronald M. Wallace & Tiernan Co., Inc., 240 So. 4th St., Rm. F, Minneapolis, Minn........ May 26, 1925
*Fink, G. J. Director of Research, Chicago Chemical Co., 6216 W. 66th Place, Chicago, Ill........ Apr. 8, 1924
Finkle, F. C. Consulting Hydraulic Engineer, 717–721 American Bank Building, Los Angeles, Calif........ June 24, 1912
Finneran, Geo. H. Supt. Water Service, 710 Albany Ave., Boston, Mass........ Feb. 18, 1921
*Fisher, E. A. Consulting Engineer, Rochester, N. Y........ June 4, 1912
Fisher, L. A. P. O. Box 198, Concord, N. C........ Jan. 27, 1914
Fisher, L. M. Acting Chief Engineer., S. C. State Board of Health, 206 Palmetto Bldg., Columbia, S. C........ Sept. 8, 1925
Fitzgerald, Howard. Chf. Engr., Buffalo Water Works, 32 North Drive, Buffalo, N. Y........ Apr. 20, 1923
Flaa, Ingwald E. Asst. Engr., Spring Valley Water Co., 425 Mason St., San Francisco, Calif........ May 14, 1915
Flack, Horace E. Executive, Dept. Legislative Reference City Hall, Baltimore, Md........ June 16, 1919
*Flad, Edward. 1312 Chemical Bldg., St. Louis, Mo........ July 23, 1919
Flannery, William. M. E., Dept., W. S. G. & E., N. Y., 97 Park Ave., Brooklyn, N. Y........ May 9, 1921
Fleming, John D. Asst. Chem. Engr., Water Divn., 34 E. Grand Ave., St. Louis, Mo........ May 17, 1927
Fleming, Virgil R. 204 Lab. App. Mech., Urbana, Ill........ Apr. 14, 1915
Flentje, Martin E. Supt. of Filtration, City Water Department, Oklahoma City, Okla........ Mar. 27, 1926
Flinn, Alfred Douglas. Secty. United Eng. Soc., Rm. 1617, 29 W. 39th St., New York, N. Y........ Mar. 1, 1916
*Folwell, A. Prescott. 7 Erwin Park, Montclair, N. J........ July 10, 1906
Foote, A. J. Hillside Arcade, Larchmont, N. Y........ Jan. 6, 1927
Foote, Francis C. Sr. Asst. Engr., Morris Knowles, Inc., 507 Westinghouse Bldg., Pittsburgh, Pa........ May 28, 1924
*Foote, Herbert B. Director, Div. Water & Sewage, State Board of Health, Helena, Mont........ Aug. 1, 1923
Ford, J. W. Engr. San Jose Water Works, 374 W. Santa Clara St., San Jose, Calif........ Jan. 26, 1924
Foreman, Charles S. Gen. Supt., Smith Bros., Inc., 600 Walsix Building, Kansas City, Mo........ June 21, 1920
Forristel, F. E. Supt. Water Works, Eveleth, Minn........ June 9, 1919
*Forsberg, Ole. Chst., Oliver Iron Mining Co., Hibbing, Minn........ Mar. 14, 1921

*Foster, Charles. Cons. Engr., 512 Selwood Bldg., Duluth, Minn. .... June 9, 1919
Foulk, C. W. Professor of Analytical Chemistry, Ohio State University, Columbus, Ohio .... June 17, 1926
Foulks, John A. Cons. Engr., 20 Beaver St., Newark, N. J. .. Dec. 23, 1921
Foutz, Charles C. Supt., Laporte Water Works, 212 Holcomb St., La Porte, Ind. .... Feb. 23, 1926
Fowler, Arthur G. Supt. Water Works, R. F. D. #3, Cumberland, Md. .... Apr. 27, 1910
Fowler, Edward A. Asst. Engr. 207 Swrge. and Wtr. Bd. Bldg., New Orleans, La. .... Apr. 27, 1910
Fox, Charles L. Asst. Supt., Pennsylvania Water Co., 712 South Avenue, Wilkinsburg, Pa. .... June 4, 1912
*Fox, Paul S. San. Engr. Bur. of Pub. Health, P. O. Box 750, Santa Fe, N. Mex. .... Oct. 31, 1924
Franchi, Emilio. Ing., Franchi Gregorini Company, S. Eustacchio, 4, Brescia, 25, Italy .... June 6, 1927
Fraser, Sam D. Superintendent, Carlsbad, Calif. .... May 20, 1926
*Freeburn, H. M. District Engineer, Penna. Dept. of Health, 508 B Midvale Avenue, Germantown, Phila., Pa. May 5, 1922
Freer, W. D. American Water Works & Elec. Co., 50 Broad St., New York, N. Y. .... Mar. 8, 1924
French, D. W. Supt. Hackensack Water Co., P. O. Box 98, Weehawken, N. J. .... May 29, 1895
*French, Dudley K. Chemist, Straus Bldg., Room 1912, 310 S. Michigan Ave., Chicago, Ill. .... May 25, 1919
French, E. V., M.E. 185 Franklin St., Boston, Mass. .... July 10, 1906
French, Troy D. Supt. City Water Dept., Box 432, Hardin, Mont. .... Oct. 13, 1926
*Fretter, A. H. Supt., Water Works, 603 S. Broadway, Medina, Ohio .... Feb. 7, 1922
Fricker, Emile. Asst. Secy., Hackensack Water Company, 624 Park Ave., Weehawken, N. J. .... Mar. 13, 1925
Friel, Francis S. Civil & Sanitary Engineer, Albright & Mebus, 1502 Locust Street, Philadelphia, Pa. .... Mar. 22, 1926
Fritz, William G. Contractor, West Orange, N. J. .... May 28, 1924
Fuertes, James H. Consulting Engineer, Woolworth Bldg., Rm., 850, 233 Broadway, New York, N. Y. .... July 10, 1906
*Fuller, George W. Cons. Engr., 170 Broadway, New York, N. Y. .... June 15, 1898
Fuller, W. A. Cons. Engr., 1917 Railway Exc. Building, St. Louis, Mo. .... Oct. 14, 1914
Fuller, Weston E., C.E. Swarthmore College, Swarthmore, Pa. .... May 27, 1922
Fullerton, Howard R. Director, Div. of San. Eng., Tennessee Memorial Bldg., Nashville, Tenn. .... Jan. 9, 1923
*Furman, Robert W. Chf. Chemist, Water Purification Works, 1443 Kenyon Drive, Toledo, Ohio .... May 25, 1922

Gaby, Frederick A. Chf. Engr., Hydro-Electric Power Com. of Ont., 190 University Ave., Toronto, Ont., Canada .... Feb. 8, 1916
*Gache, Eulogio M. Chemist & Bacteriologist, Compania Aguas Corrientes, Rosario de Santa Fe, Argentine .... Mar. 27, 1925
Gaffney, C. J. Manager Meter Repairs, 299 Myrtle Ave., Brooklyn, N. Y. .... June 17, 1926
*Gage, Stephen Dem. 310 State House, Providence, R. I. .. Apr. 27, 1925
Gager, William A. Bacteriologist & Chemist, Box 3855, St. Petersburg, Fla. .... Apr. 30, 1926
Gaillard, G. Y. Pres., New Haven Water Co., 100 Crown St., New Haven, Conn. .... May 27, 1924

Gallagher, H. A. Mgr. Water Co., Independence, Mo...... June 8, 1909
Gallaher, William U. 108 E. John St., Champaign, Ill.... Mar. 13, 1925
*Gannett, Farley. President, Gannett, Seelye & Fleming, Engrs., 204 Locust St., Harrisburg, Pa................ Nov. 29, 1919
Garman, H. O. Consulting Engineer, 2062 N. Meridian St., Indianapolis, Ind.................................... May 30, 1916
Gascoigne, George B. Consulting Sanitary Engr., 648 Leader-News Bldg., Cleveland, O..................... June 16, 1920
Gates, H. V. Prest., Hillsboro Power & Invest. Co., Hillsboro, Oregon.................................... June 7, 1904
Gaul, J. V. Local Manager, Port Costa Station, California Water Service Co., Box 867, Martinez, Calif........... May 11, 1927
*Gaunt, Percy. Chief Sanitation Chemist, c/o Shanghai Municipal Council, Shanghai, China................. Sept. 12, 1922
Gausmann, R. W. c/o Ulen & Company, No. 8 Caragheorghi St., Athens, Greece.................................. Mar. 12, 1924
*Gavett, Weston. Analyst, 312 W. 5th St., Plainfield, N. J... Nov. 10, 1914
Gaynor, Keyes C. Consulting Engineer, 527 Trimble Bldg., Sioux City, Iowa.................................. May 7, 1917
Gayton, L. D. 402 City Hall, Chicago, Ill................. Oct. 9, 1924
Gear, Patrick. Supt. Water Dept., Holyoke, Mass.......... June 24, 1913
Gebhart, Earl. Supt. of Water Works, 407 Aberdeen Drive, Middletown, Ohio.................................. May 24, 1927
Geehan, Edward A. American Water Works & Elec. Co., 50 Broad St., New York, N. Y....................... Feb. 6, 1924
Gelinas, C. E., C.E. City Engineer, Three Rivers, Quebec, Canada.. May 12, 1925
Gelston, W. R. Supt. Water Works Commission, Quincy, Ill... May 7, 1907
Gensheimer, George C. Secty. Comrs. of Water Works, Erie, Pa... June 22, 1919
*Georgia, Frederick Raymond. Rollins College, Winter Park, Fla.. May 16, 1919
Gerardy, Maurice H. 176 E. Jefferson Ave., Detroit, Mich... Mar. 16, 1922
Gerhart, Robert W. 2401 Ridge Road, Berkeley, Calif.... Dec. 13, 1926
Gerin, Maurice, M.S. Sales Engineer, Canadian Fairbanks-Morse Co., Ltd., 84 Saint Antonie St., Montreal, Que., Canada.. Feb. 10, 1926
Gerstein, H. H. 1919 W. Division St., Chicago, Ill......... Dec. 24, 1925
Gertsen, Gustav. Supt. Municipal Water Works, St. Helena, Napa County, Calif................................ May 25, 1926
*Gettrust, J. S. Supt. Akron Filt. Plant., Kent, O.......... June 8, 1921
Geupel, L. A. c/o Ulen & Company, Eleja Ujadowskie, 37 Warsaw, Poland..................................... Nov. 28, 1922
Giacomazzi, P. A. 335 Pleasant St., Santa Paula, Calif....... Nov. 8, 1923
Gibbons, Mortimer M. 99 Bryant St., Rahway, N. J.... Nov. 9, 1922
Gibson, James E. Manager & Engr., Water Dept., 14 George St., Charleston, S. C.............................. May 1, 1922
Gideon, Abraham, C. E. Mgr. Metrop. Wtr. Dist., Manila, P. I... June 8, 1909
Gidley, Henry T. Supt. Fairhaven Water Co., Fairhaven, Mass.. May 23, 1923
Gierlich, Henry S. City Engineer, City Hall, Monrovia, Calif.. Dec. 21, 1925
Giesey, Jesse K. City Engineer, City Hall, York, Pa...... Sept. 30, 1919
Gilcreas, F. Wellington. 261 Commonwealth Ave., Chestnut Hill, Mass................................ Apr. 4, 1924
Gilcrist, Charles B. Supt. Water Works, Newburgh, N. Y.. May 25, 1922
*Gilkison, George F., M.D. Chf. Chst. Water Dept., 5424 Woodland Ave., Kansas City, Mo..................... Apr. 24, 1920

*GILLESPIE, C. G. Director, State Bd. Hlth., Bur. San. Engr., Box 2085, Route 3, Broadway Ter., Oakland, Calif.	June 10, 1911
GILLIG, JOHN T. Engineer, 910 Fayette Bank Bldg., Lexington, Ky.	July 28, 1924
GINTER, ROY L. Tulsa Laboratories, Inc., 312 Richards Bldg., Tulsa, Okla.	Sept. 7. 1926
GITCHELL, H. M. Supt. Water Works, Binghamton, N. Y.	May 7, 1924
GIVEN, CHARLES W. Supt., Water Works, Monrovia, Calif.	June 8, 1922
*GLACE, IVAN M. Dist. Engr., Penna. Dept. of Health, 22 So. 22nd St., Harrisburg, Pa.	Nov. 30, 1921
GLADDING, R. D. P. O. Box 217, Wilson, N. C.	May 29, 1920
GLANNAN, PETER HUGH. Supt. Commonwealth Wtr. Co., W. O. Dvn., 22 Northfield Rd., West Orange, N. J.	June 8, 1921
GLYNNE, HARRY N. 1676 Whitney Ave., New Haven, Conn.	Aug. 12, 1922
GOBLE, W. F. 7 South First St., Alhambra, Calif.	June 17, 1926
GODFROY, F. G. Supt. Water & Light Plant, New Bern, N. C.	May 17, 1923
GOENTNER, WILLIAM B. 221 W. Mt. Carmel Ave., Glenside, Pa.	June 8, 1909
GOLDSMITH, CLARENCE. Natl. Bd. Fire Underwriters, 222 W. Adams St., Rooms 929-65, Chicago, Ill.	Dec. 27, 1915
GOLDSTEIN, MAURICE. Asst. C. E., Water Dept., 212 N. Collington Ave., Baltimore, Md.	June 9, 1922
GOOCH, W. T. 808 Speight Avenue, Waco, Texas.	Apr. 29, 1925
GOOD, TIMOTHY W. Supt. Water Works, Cambridge, Mass.	Feb. 7, 1920
*GOODELL, J. E. Chmst., 444 Woolworth Bldg., Lancaster, Pa.	Apr. 4, 1924
GOODMAN, ARNOLD H. San. Engr., Sanitary District of Chicago, 125th St. & Cottage Grove Ave., Chicago, Ill.	Dec. 23, 1921
*GOODNOUGH, X. HENRY. Chief Engr. Dept. of Public Health, Room 141, State House, Boston, Mass.	Feb. 2, 1924
GORDON, Fred G. Monadnock Bldg., Chicago, Ill	June 8, 1921
GORDON, L. O. Mgr. Operations & Engineering, Peoples Light & Power Corp., 27 William St., New York, N. Y.	Mar. 10, 1927
*GORE, WILLIAM. Cons. Engr., Confederation Life Bldg., Toronto, Ont.	Mar. 30, 1910
GORMAN, ARTHUR E. Chief Sanitary Engineer, Department of Public Works, 6743 Olympia Ave., Chicago, Ill.	Mar. 25, 1924
GOSLAU, JUSTUS. Cedar Grove, N. J.	May 13, 1924
*GOUDEY, RAY F. San. Engr., 821 Pacific Finance Bldg., Los Angeles, Calif.	Apr. 30, 1918
GOULD, RICHARD H. Sanitary Engineer, Woolworth Building, Room 850, 233 Broadway, New York, N. Y.	Feb. 6, 1924
*GRAF, AUGUST V. Chemical Engineer, St. Louis Water Works, 34 E. Grand Ave., St. Louis, Mo.	June 15, 1914
GRAHAM, GEORGE A. C.E., Nelson Bldg., Orange Ave., Daytona, Fla.	Dec. 11, 1919
GRAHAM, JAMES W. 16 Casco St., Portland, Maine.	June 4, 1912
GRANT, L. MURRAY. Supt. Water Department, 531 County-City Bldg., Seattle, Wash.	Feb. 5, 1927
GRANT, W. K. Municipal Engineer, Louisiana Fire Prevention Bureau, 619 Hibernia Bank Bldg., New Orleans, La.	May 12, 1925
GRANTHAM, C. M. Supt. Water Dept., Goldsboro, N. C.	Jan. 6, 1916
GRAY, A. C. Water Well Contractor, 22 N. Riberia St., St. Augustine, Fla.	Jan. 31, 1927
GRAY, WILLIAM J. Supt. & C.E., Springfield City Water Co., Post. Box 292, Springfield, Mo.	Apr. 23, 1924
*GREELEY, SAMUEL A. ※6 N. Michigan Ave., Rm. 1710, Chicago, Ill.	July 11, 1907

GREEN, E. W. Purchasing Agent, San Jose Water Works, San Jose, Calif. ... Oct. 27, 1925
*GREEN, F. W. Supt. Filtration & Pumping, Passaic Consolidated Water Co., Little Falls, N. J. ... Dec. 22, 1915
*GREEN, PAUL EVANS. Civil & Sanitary Engineer, 400 N. Michigan Ave., Chicago, Ill. ... Apr. 14, 1915
GREEN, RALPH H. Supt. of Water Works, P. O. Box 103, Morrison, Ill. ... Sept. 12, 1924
*GREEN, T. C. City Filtration Plant, Austin, Texas ... Apr. 27, 1925
GREENALCH, WALLACE. C.E., 37 So. Pearl St., Schuylerville, N. Y. ... July 18, 1917
GREENFIELD, R. E. Chemist, A. E. Staley Mfg. Co., 1002 W. Tuttle St., Decatur, Ill. ... Nov. 22, 1926
GREENLEE, J. L. Engineer, Asst. to Superintendent, Charlotte Water Works, Charlotte, N. C. ... June 17, 1926
GREER, FRANK E. Prin. Bact., Laboratories, Health Dept., 5458 Kimbark Ave., Chicago, Ill. ... Sept. 23, 1927
GREER, WILLARD N. Research Chemist, Leeds & Northrup Co., 4901 Stenton Ave., Philadelphia, Pa. ... Apr. 29, 1926
*GREGORY, JOHN HERBERT. Cons. Engr., Prof. Civ. & San. Eng., The Johns Hopkins Univ., Baltimore, Md. ... Apr. 1, 1910
GRIFFEY, H. A. Mgr. Water Dept., City Hall, Janesville, Wis. ... June 14, 1920
GRIFFIN, GUY E. 809 Pittsburg St., Springdale, Pa. ... July 12, 1926
GRIFFIN, H. K. Div. Mgr., California Water Service Co., Stockton, Calif. ... Sept. 26, 1927
GRIFFIN, W. G. Supt., The Frankfort Water Co., Frankfort, Ky. ... Mar. 27, 1925
GRIFFITHS, JAMES G. Supt., Kensington Water Co., Box 143, New Kensington, Pa. ... Oct. 31, 1924
GRIME, EDWIN M. Engineer of Water Service, Northern Pacific Railway, St. Paul, Minn. ... July 10, 1926
GRIMES, EDWIN L. Mgr., J. B. McCrary Eng. Corp., 798 Vedado Way, N. E., Atlanta, Ga. ... Feb. 23, 1920
GRIMMER, ALLAN K. Town Engineer, Riordon Co., Limited, Temiskaming, Que., Can. ... June 2, 1920
GROBBEL, DANIEL CORNELIUS. Asst. Secty., Bd. Wtr. Comnrs., Detroit, Mich. ... Oct. 17, 1920
*GROENIGER, WILLIAM C. Cons. San. Engr., 503 Franklin Bldg., Columbus, O. ... May 8, 1922
GRONER, E. C. 4300 W. Lake St., Chicago, Ill. ... Oct. 11, 1923
GROSS, C. P. Mgr., Water & Electric Department, Box 87, Wisconsin Rapids, Wis. ... July 31, 1924
GROSS, DWIGHT D. Board of Water Commissioners, Box 629, Denver, Colo. ... July 29, 1925
GROTZ, WILLIAM H. Assist. Engr. Bureau of Water, 50 Lakeview Ave., Buffalo, N. Y. ... June 8, 1921
GRUETZMACHER, CLARENCE S. 2108-26th St., Milwaukee, Wis. ... June 5, 1920
GUINEY, EDWARD J. Water Commissioner of Somerset, Box 592, Fall River, Mass. ... June 6, 1927
GUSHEE, EDWARD G. 2nd. Asst. Eng., Bureau of Water, 2122 N. 28th St., Philadelphia, Pa. ... May 12, 1908
GWILLIM, E. C. City Engineer, Box 130, Sheridan, Wyo. ... Mar. 6, 1926

*HABERMEYER, GEORGE CONRAD. Civil & Sanitary Engr., 57 Chemistry Bldg., Urbana, Ill. ... Apr. 14, 1915
HABESHIAN, YERANOS B. Chemist, Filtration Plant, W. 32nd & Division Ave., Cleveland, Ohio ... Sept. 28, 1926
HACKETT, LEWIS E. 313 N. Capitol Ave., Lansing, Mich. ... May 28, 1924
HAGINS, C. E. 314 Luzerne St., Westmont, Johnstown, Pa. ... Sept. 7, 1926

*HALE, FRANK E., PH.D. Director of Laboratories, Mt. Prospect Laboratory, Brooklyn, N. Y.	May 12, 1908
HALE, RICHARD A. Chief Engineer, Essex Company, Lawrence, Mass.	May 28, 1924
HALE, RICHARD KING, C.E. 545 Chestnut Hill Ave., Brookline, Mass.	June 10, 1911
HALL, ARTHUR J. Bacteriologist & Plant Supt., 316 W. Prospect St., Appleton, Wis.	Jan. 21, 1927
HALL, H. F. Chf. Engr., Water Works Dept., Northern Apts., Sarnia, Ont., Can.	June 21, 1920
HALL, H. G. Supt. Pub. Util. Comn., Ingersol, Ont., Can.	Mar. 26, 1923
HALL, HARRY R. Dpty. Chf. Engr., Washington Suburban Sanitary District, Hyattsville, Md.	May 8, 1915
HALL, JOHN W. Supt., Choteau, Montana	May 23, 1925
HALL, ROLAND B. 705 Myrtle St., N. E., Atlanta, Ga.	Sept. 22, 1925
HALL, WARREN E. Dist. Eng. U. S. Geological Survey, 6 Government St., Asheville, N. C.	Dec. 8, 1923
HALPIN, THOMAS F. c/o A. P. Smith Mfg. Co., East Orange, N. J.	July 18, 1901
HAMILTON, CHAS. A., M.E. Messrs. Burd, Giffels & Hamilton, 421 Kelsey Office Bldg., Grand Rapids, Mich.	Dec. 29, 1926
HAMMERLY, FRED V. 536 Call Bldg., San Francisco, Calif.	Jan. 2, 1924
HAMMOND, R. B. Supt. Water Dept., Blue Island, Ill.	June 8, 1919
HAMMOND, W. H. Supt., Lindsay Water Works, Lindsay, Ont., Can.	June 24, 1914
HANCOCK, EDWIN. Cons. Engr., 2047 Ogden Ave., Chicago, Ill.	Nov. 12, 1919
HANLEY, JOHN P. Inspector Water Service, Water Dept. Ill. Central R. R. Co. I. C. Sta., Chicago, Ill.	Mar. 13, 1925
HANNA, DAVID MCLEAN. Service Supt., City Hall, Windsor, Ont., Can.	June 9, 1920
*HANNAN, FRANK. Chemist, Filtration Plant, 285 Willow Avenue, Toronto-8, Ont., Canada	July 30, 1921
*HANSEN, A. E. Hyd. and San. Engr., 116 W. 39th St., New York, N. Y.	Dec. 31, 1917
HANSEN, J. C. Water Works Trustee, 551 West Broadway, Council Bluffs, Iowa	Feb. 27, 1924
*HANSEN, PAUL. c/o Pearse, Greeley & Hansen, #6 N. Michigan Ave., Rm. 1710, Chicago, Ill.	June 4, 1912
*HARDER, E. C. Sect., American Bauxite Co., 1111 Harrison Bldg., Philadelphia, Pa.	Oct. 16, 1924
HARDER, H. J. Civ. & San. Engr., 129 Market St., Paterson, N. J.	Dec. 4 1920
HARDIN, EUGENE A. Engineering Division, Water Works Park, Detroit, Mich.	Nov. 10, 1925
HARDING, GEORGE. Mgr., 1105 Paulsen Building, Spokane, Wash.	Oct 10, 1912
*HARDING, JAMES C., C.E. 170 Broadway, New York, N. Y.	July 12, 1922
*HARDING, JAMES C., JR., C.E. 170 Broadway, New York, N. Y.	June 6, 1922
HARDING, JOHN H. Supt. Water Works, La Porte, Ind.	May 14, 1918
*HARDY, EDWARD DANA. Asst. Engr., United States Engineer's Office, Old Land Building, Room 250, Washington, D. C.	May 12, 1908
HARGER, FRANK D. Chief Operator, City Filtration Plant, 1249—8th St., Columbus, Ind.	Apr. 10, 1926
HARPER, L. V. Mgr., Chelan Electric Co., Chelan, Wash.	Aug. 19, 1914
HARRIS, F. M. Supt. Filter Plant, 112 5th St., Lewiston, Idaho	Aug. 5, 1924
HARRIS, HOWARD A. Asst. Engr. California Water Service Co., 412 Hunter-Dulin Bldg., San Francisco, Cal.	Aug. 15, 1927

Harris, R. C. Commissioner of Works, City Hall, Toronto, Ont., Can. ... May 12, 1914
Harris, Shirley W. Mgr., McWane Cast Iron Pipe Co., Rm. 1288, 208 La Salle St., Chicago, Ill. ... Feb. 17, 1927
Harrison, John H. Supt. Kingston Wtr. Wks. Dept., City Hall, Kingston, N. Y. ... Mar. 19, 1924
Harrison, Ronald. B. A. Sc., Engr. & Supt. Scarboro Twnshp. Water Works, Birch Cliff, P. O. Toronto, Canada ... Jan. 30, 1924
Harrub, C. Nelson. 705 Fourth & First Ntl. Bnk. Bldg., Nashville, Tenn. ... Apr. 16, 1914
Harshbarger, Elmer Dwight. Pres., Pitt Construction Co., 239 Gladstone Rd., Squirrel Hill Sta., Pittsburgh, Pa. ... June 28, 1924
Hartmann, F. W. Superintendent Water Works, Iron Mountain, Mich. ... July 20, 1925
*Haskins, Capt. Chas A. Consulting Engineer, 517 Finance Bldg., Kansas City, Mo. ... June 19, 1924
Hassler, Samuel F., M.D. Supt. Public Safety, 500 No. 2nd St., Harrisburg, Pa. ... Mar. 29, 1920
Hatch, Aram H. Chief Chemist in charge of Water Purification Plants of Canal Zone, P. O. Box 283, Ancon, Canal Zone ... Aug. 20, 1927
Hatch Donald M. Supt., Dept. of Water Supply, 610 Wildwood Ave., Jackson, Mich. ... May 16, 1920
Hatch, Theodore. 112 Pierce Hall, Harvard University, Cambridge, Mass. ... Jan. 6, 1926
*Hatfield, William Durrell. Sewage Disposal Plant, Sanitary District of Decatur, Decatur, Ill. ... Jan. 31, 1917
*Hatton, T. Chalkley. 490 Broadway, Milwaukee, Wis. ... June 11, 1902
Haupt, B. W. Secty., Roaring Creek and Bear Gap Wtr. Cos., 204 E. Sunbury St., Shamokin, Pa. ... Mar. 16, 1922
Havens, William L. Associate, Geo. B. Gascoigne, 1149 Leader Bldg., Cleveland, Ohio ... June 5, 1926
Havill, Harold Thomas. Asst. Engr., Dept. Wtr. Sup. N. Y. C., 51 North St., Mt. Vernon, N. Y. ... June 11, 1902
Hawkins, Horace C. Supt., Municipal Water Plant, Oskaloosa, Iowa ... Nov. 4, 1926
*Hawley, Geo. W. Engr. in Charge, Water Supply Investgn. & Constn., East Bay Water Co., Oakland, Calif. ... June 30, 1922
Hawley, George W. Secty. & Treasr. Water Co., Dixon, Ill. June 21, 1920
*Hawley, John B. Cons. Engr., 403 Cotton Exchange, Ft. Worth, Tex. ... June 1, 1923
Hawley, W. C. Chf. Engr. & Genl. Supt., Pennsylvania Water Co., 712 South Ave., Wilkinsburg, Pa. ... Apr. 27, 1910
*Haydock, Charles. 2726 West Somerset St., Philadelphia, Pa. ... Feb. 17, 1919
Hayford, B. B. Superintendent Water Works, Waukesha, Wis. ... June 8, 1909
Hays, C. D. Huron, South Dakota ... Oct. 31, 1922
Haywood, G. C. Secy., Metropolitan Water Supply Dept., 56 James St., Perth, W. Australia ... Oct. 6, 1915
*Hazen, Allen. Civil Engineer, 25 W. 43rd St., New York, N. Y. ... May 27, 1896
*Hazlehurst, George H. Chf. San. Engr., Montgomery, Ala. Nov. 1, 1914
Healey, Thomas. Supt. Davenport Water Co., 206 Kahl Bldg., Davenport, Iowa ... May 28, 1924
Heard, Albert. Supt. & Treas. Water Works, Hagerstown, Md. ... July 18, 1907
Heater, R. O. Mgr., Heater Well Drilling Co., Cary, N. C. Dec. 29, 1924

Heath, Ray. Laboratories of Dept. of Health, City Hall, Toronto, Canada........ June 26, 1924
Hebbring, A. W. Supt. Wauwatosa Water Works, 292 Kenyon Ave., Wauwatosa, Wis........ Sept. 8, 1923
Hechmer, Carl A. Dept. Engr., Mtnce. & Optg. Dept., Wash. Subn. San. Dist., Hyattsville, Md........ Nov. 3, 1919
Heermans, H. C. Manager Water Works Co., Hoquiam, Wash........ June 26, 1886
Heffernan, David A. Supt. Water Dept., Milton, Mass........ May 28, 1924
Helling, Harry A. Supt., Consol. Water Co., 86 Beekman St., North Tarrytown, N. Y........ Jan. 17, 1922
Helmreich, L. W. Supt., Capital City Water Co., Box 32, Jefferson City, Mo........ Feb. 14, 1927
Helwick, J. W. V. P. & Gen. Mgr., Oregon-Washington Water Service Co., 721 Corbett Bldg., Portland, Ore........ May 24, 1927
Henby, Wm. H. Pres., St. Louis County Water Co., 6600 Delmar Ave., St. Louis, Mo........ May 6, 1915
Henderson, Charles R. Mgr. Davenport Water Co., Davenport, Iowa........ June 18, 1901
Henderson, Clark T. Chairman Water Commission, 317 Chapin Lane, Burlingame, Calif........ Mar. 10, 1926
Hendrick, Wallace M. 11 Clarkson Ave., Brooklyn, N. Y........ May 10, 1915
Hendricks, R. W. Engr. Hyd. Dept. Undtrs. Labs., 207 E. Ohio St., Chicago, Ill........ Apr. 2, 1923
Hendry, W. A. Chf. Engr., Water Works, 628 West 9th St., Waterloo, Ia........ Nov. 25, 1921
Henshaw, Franklin. Supt. Water Works, Scarsdale, N. Y........ Sept. 21, 1920
Herr, J. O. Superintendent, Tintern Manor Water Co., Long Branch, N. J........ June 5, 1916
Hess, Edwin Wesley. Cons. Engr., 2–6 Murray Bldg., Clearfield, Pa........ Jan. 16, 1920
Hetzer, Mentor. Mgr. Moundsville Water Co., Moundsville, W. Va........ Nov. 17, 1916
Heyward, T. C., B.S. Mech. & Elect. Engr., 1100 Realty Bldg., Charlotte, N. C........ June 22, 1923
Hezzelwood, Lawrence Lyman. Engr., Des Moines Munic. Water Plt., 1003 Locust St., Des Moines, Iowa........ Aug. 13, 1924
Hibbs, Albert S. Ass't Supt., Akron City Water Works, Municipal Bldg., Akron, Ohio........ Sept. 12, 1922
Hibschman, Charles A. Supt., Ambler Springs Water Co., Ambler, Montgomery Co., Pa........ Aug. 11, 1924
Hickox, J. R. Hyd. Engr., Chicago, Burlington & Quincy R. R., Room 1501, Burlington Bldg., 547 W. Jackson Blvd., Chicago, Ill........ June 17, 1926
Higgins, Lafayette, C.E., 1144 W. 25th St., Des Moines, Iowa........ Dec. 10, 1915
Highland, Scotland G. General Manager, Clarksburg Water Board, Clarksburg, W. Va........ Feb. 10, 1913
Hill, Albert B. Cons. C.E., 100 Crown St., New Haven, Conn........ Oct. 30, 1914
Hill, Harry Prescot. 40 Kennedy St., Manchester, England........ Nov. 6, 1924
Hill, John W. Cons. Engr., Brotherhood Bldg., Cincinnati, Ohio........ June 26, 1886
*Hill, Nicholas S., Jr. Cons. Engr., 112 E. 19th St., New York, N. Y........ June 18, 1901
Hill, O. C. Superintendent of Water Wks., Louisburg, N. C........ Aug. 28, 1926
Hinchman, T. H. Cons. Engr., 800 Marquette Bldg., Detroit, Mich........ June 1, 1923

HINMAN, JACK J., JR. Assoc. Prof. of Sanitation, Univ. of Iowa, P. O. Box 313, Iowa City, Iowa................ Apr. 21, 1915
*HOAD, PROF. WILLIAM CHRISTIAN. 1028 Martin Place, Ann Arbor, Mich.. June 24, 1913
HOAG, GEORGE E. Fire Prevention Engineer, New York Fire Insurance Rating Organization, Suburban Division, 85 John St., New York, N. Y......................... June 2, 1920
HOAG, PERCY LATOURETTE. Hyd. Engr., Manhasset, L. I., N. Y. June 28, 1919
HOAGLAND, IRA GOULD. Secty., National Automatic Spklr. Assn., 80 Maiden Lane, New York, N. Y............... Apr. 27, 1910
HODGES, GEORGE C. Chemist, Consolidated Water Co., 712 Washington St., Utica, N.Y......................... June 11, 1924
HODGMAN, BURT B., C.E. 50 Church St., New York, N. Y..... July 18, 1907
HODKINSON, THOMAS. C.E., Supt. Water Works, 14 King St., London, Ont., Can................................ Apr. 15, 1913
HOFFMAN, FLOYD A. Supt. of Water Dept., Box 413, Morristown, N. J.................................... July 12, 1926
HOFFMASTER, GEORGE EDWARD. 32 Grove Ave., Larchmont, N. Y.. May 13, 1916
HOGAN, JOHN PHILIP. Cons. Engineer, 84 Pine St., New York, N. Y.. June 9, 1920
HOLBROOK, A. A. General Mgr., Stroudsburg Water Supply Co., Stroudsburg, Pa............................. Jan. 14, 1925
HOLBROOK, ARTHUR R., C.E. c/o Fuller & Maitland, Walsix Bldg., Rm. 206, Kansas City, Mo................. Apr. 30, 1923
HOLDREDGE, NEIL C. P. O. Box 615, Haskell, N. J......... May 26, 1924
*HOLDSWORTH, VICTOR. 4 Corporation St., Dewsbury, Yorks, England.. Sept. 3, 1925
HOLE, R. J. 1313 Cherry St., St. Petersburg, Fla........... Apr. 26, 1926
HOLLAND, RAY KINGSBURY. Consulting Engineer, 106 E. Liberty St., Ann Arbor, Mich......................... Jan. 17, 1919
HOLMAN, E. T. Chief Inspector, Tenn. Inspec. Bur., 1034 Stahlman Bldg., Nashville, Tenn..................... Jan. 7, 1924
HOLMES, A. G. Drawer P., Wilkinsburg Branch P. O., Pittsburgh, Pa.................................... July 10, 1906
HOLMES, J. A. Chief Chemist, Chicago Chemical Co., 6216 W. 66th Place, Chicago, Ill............................ May 25, 1926
*HOLMQUIST, C. A. State Dept. of Health, Albany, N. Y..... Apr. 27, 1923
HOLT, FRANK C. Supt., City Water & Light Works, 220 North Van Buren St., Newton, Ill.......................... Jan. 26, 1926
HOLTZ, J. B. Water Commissioner, Dillon, Mont............ Jan. 17, 1927
HOLWAY, A. S. 6414 North Fairfield Ave., Chicago, Ill...... June 9, 1921
HOLWAY, W. R. Lock Joint Pipe Co., Ampere, N. J......... Feb. 18, 1925
*HOMMON, HARRY B. Sanitary Engr., U. S. P. H. S., 420 Call Bldg., San Francisco, Cal............................ July 27, 1921
HONNESS, GEORGE GILL. Grand Gorge, N. Y.............. Apr. 4, 1924
HOOPER, THOMAS H. Supt. Water Works, Winnipeg, Manitoba, Canada..................................... Mar. 5, 1924
HOOPES, EDGAR M., JR. Water Comnr., Box 895, Wilmington, Del.. Apr. 10, 1923
HOOT, RALPH A. Supt., Filter Plant, Highland Park Water Dept., Highland Park, Mich......................... Mar. 10, 1926
*HOOVER, CHARLES P. Chemist, Filtration Plant, Columbus, Ohio.. May 14, 1913
*HOOVER, CLARENCE B. Supt. Wtr. & Swge. Disp., 6th and Broad Sts., Columbus, Ohio.......................... Apr. 18, 1923
*HOPKINS, CHARLES COMSTOCK. Hydraulic and Sanitary Engr., 349 Cutler Building, Rochester, N. Y.......... June 10, 1911
*HOPKINS, EDWARD S. Montebello Filters, Hillen Road, Baltimore, Md.. June 13, 1921

Hopkins, Edwin W. Consolidated Water Co., 712 Washington St., Utica, N. Y. .... Aug. 13, 1925
Hopkins, Franklyn C. Prest. Consol. Water Co., 712 Washington St., Utica, N. Y. .... June 16, 1919
Hopkins, Newton F. Civil Engineer, 801 Home Trust Bldg., Pittsburgh, Pa. .... July 18, 1907
Hopper, Walter C. Supt. Passaic Consol. Water Co., 145 Prospect St., Passaic, N. J. .... June 10, 1911
Horn, J. F. Prest. Water Co., Vandergrift, Pa. .... Oct. 10, 1919
Horne, Alfred Dewey. 4820 Fletcher St., Chicago, Ill. .... Nov. 12, 1920
Horner, Charles M. Supt. Water Works Co., 1705 State St., East St. Louis, Ill. .... June 24, 1903
Horner, H. H. Vice Pres. & Supt., The Birmingham Water Works Co., 2114 1st Ave., Birmingham, Ala. .... Dec. 29, 1924
Horning, Fred A. Mgr., Superior Elec. Light & Water Works, Superior, Mont. .... Apr. 10, 1926
Horstmann, F. B. Chemical Engineer, 654 No. Lamon Ave., Chicago, Ill. .... Jan. 20, 1911
Horton, Robert E., H.E. R. D. #1, Voorheesville, N. Y. .... Jan. 20, 1911
*Horton, Theodore. Chf. San. Engr. Dept. of State Engineering, 346 State St., Albany, N. Y. .... July 18, 1907
Hostetler, Ervin W. Supt. of Distribution, Iowa City, Iowa .... June 6, 1927
Hotchkiss, Harry E. Chemist, 31 N. Mill St., New Castle, Pa. .... Mar. 16, 1927
Hough, Laurence C. Dist. Mgr. Pitometer Co., 55 Bourne St., Jamaica Plain, Mass. .... Jan. 17, 1919
Houser, George C. Metcalf & Eddy, 1300 Statler Bldg., Boston, Mass. .... Nov. 24, 1925
Houston, L. J., Jr. City Mgr., Fredericksburg, Va. .... Feb. 17, 1919
*Howard, Charles D. Chemist, State Bd. of Hlth., Concord, N. H. .... Feb. 18, 1921
Howard, John L. Ashburton Place, Boston, Mass. .... May 31, 1924
Howard, N. J. Bacteriologist in Charge, Water Purif., Island Filtration Laboratories, 410 Lake Shore, Centre Island, Toronto, Ont., Canada .... June 21, 1920
Howe, M. J. Supt., Bd. Water Comnrs., Lake City, Minn. .... Feb. 11, 1922
Howell, David J., C.E. Union Trust Building, Washington, D. C. .... Oct. 10, 1914
Howell, Wm. Superintendent Water Works, Marion, N. Y. .... June 17, 1926
Howes, D. W. Tenafly, N. J. .... May 25, 1922
Howland, E. Robert. The British Pitometer Co., 39 Victoria St., London, S. W. I., England .... Apr. 22, 1914
Howland, J. Hastings. Engr., National Board of Fire Underwriters, 85 John St., New York, N. Y. .... May 15, 1924
*Howson, Louis R. Alvord, Burdick & Howson, 130 Eighth Ave., LaGrange, Ill. .... Apr. 24, 1916
Hoy, Joseph A. Asst. Genl. Foreman, Water Dept., 18 East Worcester St., Worcester, Mass. .... May 15, 1922
Hubbard, A. M. Supt., Municipal Water Dept., Box Letter H, Troy, Montana .... Nov. 10, 1925
*Hubbell, Clarence W. Cons. Engr., 2348 Penobscot Building, Detroit, Mich. .... June 24, 1903
Hudson, John. Compania Aguas Corrientes, San Nicolas, F.C.C.A., A.R. .... Aug. 19, 1924
Hudson, Leo. 802 Wabash Bldg, Pittsburgh, Pa. .... July 7, 1913
Huggans, R. D. Mgr. Water Works, Streator, Ill. .... Apr. 19, 1915
Hughes, W. P. City Engr. & Water Supt., City Hall, Lewiston, Idaho .... Sept. 18, 1925

Hughes, William James. Asst. Engr. for Maintenance, Melbourne & Metropolitan Board of Works, 110 Spencer St., Melbourne, Victoria, Australia.................... Sept. 7, 1927
*Humason, N. J. Supt. of Filtration, Elyria Water Works, Lorain, Ohio.. Mar. 13, 1925
Hume, W. R. Mechanical Engineer, c/o Hume Pipe Co., Melbourne, Australia.. June 6, 1927
Humphreys, Chester C. Superintendent Filtration, Tampa Water Works, Tampa, Fla............................ June 17, 1926
Hunt, Wm. G. Pump House Residence, R. R. No. 4, Peterborough, Ont., Can.................................. Apr. 29, 1924
Hunter, Charles A., Asst. Dctr. State Hlth. Lab., Vermilion, S. Dak....................................... July 18, 1923
Hunter, George A. 512 16th Street, Oakland, Calif......... Aug. 28, 1922
Hunter, Henry G. 598 Union Ave., Montreal, Canada..... June 10, 1911
*Hunter, T. B. Consulting Engineer, 505 Rialto Bldg., San Francisco, Calif....................................... July 10, 1906
Hunter, W. W. Supt., Canal & Water Works, Augusta, Ga.. May 24, 1922
Huntington, C. C. Supt. Water Department, Eureka, Kansas.. Mar. 19, 1927
Hurd, Charles H. 1405 Merchants Bank Bldg., Indianapolis, Ind.. Aug. 11, 1914
Hurdle, Reginald T. Supt. of Water & City Engr., Box 546, Glendive, Mont.................................... July 6, 1926
Hurlbut, William W. 207 South Broadway, Los Angeles, Calif.. May 28, 1924
Hurtgen, P. J. Director Public Works, City Hall, Kenosha, Wis... May 21, 1923
Huse, George A. Treas. & Mgr., Northern Illinois Water Co., 132 S. Dearborn Ave., Kankakee, Ill.............. June 6, 1927
Hutchins, Will A. Secty. and Supt. Water Co., 196 Van Buren St., Freeport, Ill................................ Nov. 30, 1920
Hutchinson, Alexander, C.E. Dctr. Drummond, McCall & Co., P. O. Box 660, Montreal, P. Q................ May 5, 1921
Hutson, A. Cary. 85 John St., New York, N.Y.............. Apr. 29, 1924
*Hutton, Harold S. Sanitary Engineer, 233 Oliver Ave., Pittsburgh, Pa.. Apr. 1, 1920
Huy, Harry F. Genl. Mgr., Western New York Water Co., 704 Electric Building, Buffalo, N. Y................... Apr. 13, 1916
*Hyde, Charles Gilman. Cons. Hyd. & San. Engr., Prof. San. Eng., Univ. of Cal., Berkeley, Cal.............. July 18, 1907
Hyde, Ralph H. Vice President & General Manager, The Campbell Water Co., Box 1, Campbell, Calif........... May 17, 1927
Hyman, H. H. Mgr. Miami Water Co., Miami, Fla........... Apr. 16, 1916

Ihrig, Charles O. Supt., Hazard Water Co., P. O. Box 1146, Hazard, Ky... Apr. 9, 1925
Inman, C. E. Comnr. & Supt. Water Works, Warren, O....... May 24, 1921
Inoue, S. 290 Harajiku, Tokyo, Japan..................... July 18, 1907
Isaac, F. N. Sec. G. M., The Hanford Water Co., Hanford, Cal.. May 12, 1908
Ivanissevich, L. Mitre 740, Mendoza, A. R................ Jan. 6, 1927
Iwasaki, Tomihisa. Water Wks. Dept., Suido Kakucho, Tokyo-Shiyakusho, Japan............................. Jan. 9, 1923

Jack, Grant R. Commissioner of Works, 787 Coswell Ave., Toronto, Ont., Canada.............................. Mar. 16, 1926
Jackson, C. B. Supt. City Water Corp., Fresno, Cal....... Aug. 18, 1920
*Jackson, Daniel D. San. Expt., Havemeyer Hall, Columbia University, New York, N. Y......................... Jan. 31, 1910

Jackson, H. W. Supt. Water Works, 912 Arctic St., Antigo, Wis. .... Aug. 7, 1924
Jackson, John F. Supt. Water Works Dept., 115 W. Fourth St., Rochester, Mich. .... May 23, 1923
Jacobs, Joseph. Cons. C. E., 613–616 Thomson Bldg., Seattle, Wash. .... July 30, 1920
Jacobs, S. Willard. Chem. Engr., 9 East 41st St., New York, N. Y. .... Feb. 5, 1919
Jacobsen, Robert T. Engineering News-Record, 10th Ave. & 36th St., New York, N. Y. .... Apr. 16, 1914
Jaeger, C. P. Commissioner, Water Dept., City Hall, Cleveland, Ohio .... June 11, 1924
Jahns, L. O. Sanitary Engineer, 520—19th Ave., Moline, Ill. .... May 26, 1927
*Janzig, Alexander C. Wtr. Bact. & Chst. Filtn. Plant, 904 20th Ave., S. E., Minneapolis, Minn. .... Oct. 11, 1921
Jarrett, J. M. Supt. Water Works, Box 1602, Southern Pines, N. C. .... June 6, 1927
Jarvis, Capt. Alexander Charles. Jens Kofoedsgade 4, Copenhagen, Denmark .... May 5, 1914
Jenkins, David. The New Jersey Zinc Co., Franklin, N. J. .... Oct. 14, 1922
Jenkins, E. J. Superintendent of Distribution, Philadelphia Suburban Water Co., Lansdowne, Pa. .... Feb. 9, 1925
Jenks, Harry N. Dept. of Civil Engineering, Iowa State College, Ames, Iowa .... Jan. 26, 1917
*Jenne, Lyle L. Sanitary Engr., Bureau of Water, Front and Fulton Sts., Chester, Pa. .... June 30, 1921
Jensen, J. Arthur. Supervisor Water Works Dept., Minneapolis, Minn. .... Apr. 15, 1910
Jensen, J. Chris. Municipal Water Works, Council Bluffs, Iowa .... June 3, 1912
Jette, Jos. Arthur. Asst. Supt. Montreal Water Works, 1509 Darling St., Montreal, P. O., Canada .... May 25, 1926
Jeup, B. J. T. Chf. Engr., Indianapolis Water Co., 113 Monument Circle, Indianapolis, Ind. .... Feb. 22, 1920
*Jeup, Barnard H. 2415 Talbott Ave., Indianapolis, Ind. .... May 12, 1925
Johns, Herbert M. Supt. Hanford Water Co., Hanford, Calif. .... Oct. 17, 1920
Johnson, Edgar W. Asst. Engr., Water Dept., 3821 Elliot Ave., Minneapolis, Minn. .... July 13, 1917
*Johnson, Col. George A. Cons. Engr., 150 Nassau St., New York, N. Y. .... July 18, 1907
Johnson, H. E. Supt. Public Utility Plant, Winona, Miss. .... Dec. 22, 1912
Johnson, R. F. 217 Hanchett St., Saginaw, Mich. .... May 23, 1923
Johnson, Samuel C. Room 407, C. & O. Station, Huntington, W. Va. .... Apr. 9, 1923
*Johnson, W. Scott. Division of Sanitary Engineering, State Board of Health, Jefferson City, Mo. .... Feb. 16, 1924
Johnston, William J. Supt. Water Works, Marquette, Mich. .... Mar. 10, 1917
Jones, Allen A. 12053 Lake Ave., Suite 12, Cleveland, Ohio .... Feb. 23, 1924
Jones, Earl F. Mgr., Washington Water, Light & Power Co., Washington, Ind. .... Mar. 23, 1927
Jones, F. Wayland. Water Works Supt., P. O. Box No. 112, Manteca, Calif. .... May 24, 1927
*Jones, Frank Woodbury. Sanitary Chemist, 4293 E. 134th St., Cleveland, Ohio .... May 23, 1923
Jones, H. Seaver. V. Prest., East Jersey Pipe Co., 7 Dey St., New York, N. Y. .... July 16, 1922
Jones, Harvey P. 1601 Second National Bank Bldg., Toledo, Ohio .... July 30, 1922

*Jones, Hiram F. Supt. Pumping & Filtration, Elmira Water Board, Elmira, N. Y.	July 18, 1907
Jones, J. M. Bristol & Warren Water Works, Bristol, R. I.	May 9, 1916
Jones, Morris S. Asst. Chief Engr. Water Dept., 602 Central Bldg., 30 N. Raymond Ave., Pasadena, Calif.	Oct. 28, 1924
Jones, W. T. Superintendent Water Works, Hollywood, Fla.	Dec. 11, 1922
Jones, Wm. Allen. Village Manager, Huntington Woods, P. O. Royal Oak, Mich.	May 24, 1927
Jones, William Nelson. 8001–13th St., Tampa, Fla.	Apr. 14, 1914
Joplin, Joseph W. 421 W. Emerson St., Princeton, Ind.	Feb. 9, 1925
Jordan, Frank C. Secretary Indianapolis Water Co., 113 Monument Circle, Indianapolis, Ind.	June 10, 1911
*Jordan, Harry E. Sanitary Engr., Indianapolis Water Co., 113 Monument Circle, Indianapolis, Ind.	Oct. 7, 1919
Jordan, John G. Shields, Jordan & Roe, Engineers, 625 Cornelia Ave., Chicago, Ill.	June 6, 1927
Jorgensen, H. A. Supt., Municipal Water Works, 385 Elm Ave., San Bruno, San Mateo Co., Calif.	May 28, 1926
Judson, John W. Chf. Acct. Dpt. Sts. & Pub. Impvts., Newark, N. J.	June 12, 1920
Jutz, Charles E. Treas. St. Louis County Water Co., 6600 Delmar Ave., St. Louis, Mo.	Apr. 12, 1920
Kable, Edgar P. Genl. Mgr. York Water Co., 42 East Market St., York, Pa.	Nov. 10, 1917
Kapp, John J., Jr. Supt., Municipal Water System, 378 Morrisse Ave., Haldeon, N. J.	Mar. 29, 1927
Kay, Edgar B. Chf. Hyd. & San. Branch, Q. M. C., 1840 Mintwood Place, N. W., Washington, D. C.	Apr. 27, 1910
Kayanoki, Hiroyuki. City Planning Bureau, Dept. of Home Affairs, Tokio, Japan	June 30, 1923
Keating, Charles Stanley. Designing Engineer, City Engineer's Office, Syracuse, N. Y.	May 16, 1919
Keckler, Clarence M. Sanitary Engineer, 15 Clinton Place, Red Bank, N. J.	Sept. 14, 1927
Keefer, Clarence Edward. Engineer of Sewage Disposal, Bureau of Sewers, City Hall Annex No. 1, Baltimore, Md.	Feb. 23, 1920
Keenan, F. E. Superintendent of Water Wks., Gunnison, Colo.	Feb. 14, 1927
Keils, Anthony. Supt., Mt. Clemens Water Works, 38 Moross Ave., Mt. Clemens, Mich.	June 8, 1909
Keis, F. J. Consulting Engineer, Sunset Building, Fort Lauderdale, Fla.	Apr. 23, 1927
Keith, J. Clark. Chf. Engr., Essex Border Util. Comn., 302 Ouellette Ave., Windsor, Ont., Can.	Mar. 21, 1923
Keliher, Timothy. Supt. Williamsport Water Co., Williamsport, Pa.	Feb. 15, 1917
Keller, George John. Sect. & Gen. Mgr., Iowa City Water Co., Iowa City, Iowa	Nov. 15, 1914
Keller, John N. Deputy County San. Engr. & Surveyor, 1126 Harding Drive, Toledo, Ohio	May 12, 1925
Kelley, C. H. Supt. Wichita Water Co., 301 No. Main St., Wichita, Kans.	July 5, 1924
Kellner, Hugh. Chf. Engr. City Water Works, 74 Moy Ave., Windsor, Ont., Can.	Feb. 28, 1923
Kellogg, James Wilford. Bct. & Chst., State Lab. of Hyg., Raleigh, N. C.	June 10, 1921
Kelly, Earl W. Engineer, Water & Light Department, Duluth, Minn.	Dec. 7, 1926

*KELSEY, J. W. Genl. Supt. Bureau of Water, St. Paul, Minn.	May 13, 1913
KEMBLE, F. T. Secy., New Rochelle Water Co., 238 Main St., New Rochelle, N. Y.	June 24, 1915
KEMPKEY, AUGUSTUS. Cons. Engr., 416 Hobart Bldg., San Francisco, Calif.	June 10, 1923
KENDALL, THEODORE REED. Eng. Editor, *The American City*, 303 So. Broadway, South Nyack, N. Y.	Mar. 13, 1919
KENZLE, C. F. Asst. to Pres., Federal Water Service Corp., 27 William Street, New York, N. Y.	Aug. 17, 1927
KEOGH, WM. J. Asst. Engr. Dept. of Water, 9350-209th St., Queens, N. Y.	June 13, 1922
KEPNER, DANA E. Director, Div. Sanitary Engineering, Colorado State Board of Health, 420 State Office Bldg., Denver, Colo.	Oct. 31, 1925
KERLIN, E. M. Sullivan, Indiana	May 12, 1925
KETCHAM, VALENTINE O. Gen. Mgr. Stamford Water Co., 51 Summer St., Stamford, Conn.	July 6, 1926
KIENLE, JOHN A. Vice President, Mathieson Alkali Works, Inc., 250 Park Ave., New York, N. Y.	June 8, 1909
KIERNAN, MICHAEL J. 15 Caroline, Worcester, Mass.	Apr. 28, 1925
KIERSTED, WYNKOOP, JR. 614 Interstate Bldg., Kansas City, Mo.	Apr. 27, 1925
KILLAM, SAMUEL E. Supt. Distbn. Sctn. Wtr. Divn., 1 Ashburton Place, Boston, Mass.	Nov. 25, 1915
*KIMBERLY, A. ELLIOT. San. Engr., 8 E. Long St., Columbus, Ohio	May 23, 1923
KINDER, MYRON C. Commissioner of Water, City Bldg., Youngstown, Ohio	Oct. 16, 1925
KING, ARNOTT CHISWELL. 145 Hamilton Ave., Paterson, N. J.	Apr. 20, 1921
KINGMAN, HORACE. Comr. and Supt., City Hall, Brockton, Mass.	Mar. 17, 1916
KINGSLEY, JOHN F. Supt. Water Works, Covington, Ky.	June 9, 1920
KINTER, S. G. Supt., Water Co., Jersey Shore, Pa.	May 24, 1922
KIRBY, R. W. Manager, Mullens Water Works, Mullens, W. Va.	Oct. 7, 1924
*KIRCHOFFER, WILLIAM GRAY. San. & Hyd. Engr., 22 N. Carroll St., Madison, Wis.	Jan. 31, 1923
KITCHEN, H. B. Mgr. Watsonville City Wtr. Wks., 31 E. 3rd St., Watsonville, Calif.	Feb. 16, 1924
KITE, ROBERT P. The Dorr Co., 1503 Candler Bldg., Atlanta, Ga.	Mar. 7, 1927
KITTREDGE, H. S. Sect.-Treas., Water Works, 374 W. Santa Clara St., San Jose, Calif.	Apr. 12, 1927
KITTREDGE, HARRY C. Consulting Engineer, 805 Union Trust Bldg., Rochester, N. Y.	Mar. 30, 1926
*KIVELL, WAYNE A. Sanitary Engineer, Dorr Co., 310 South Michigan Ave., Chicago, Ill.	May 28, 1924
KLAPP, CARL F. Supt. Water Works, Everett, Wash.	Oct. 7, 1917
KLARE, R. W. Mgr., Northern Indiana Power Co., Wabash, Ind.	June 24, 1915
KLAUS, FRED J. Chief Engr., East Bay Water Co., 512-16th St., Oakland, Calif.	Oct. 2, 1915
KLEIN, WILLIAM I. Cons. Engr., 41 Cortlandt St., New York, N. Y.	July 1, 1913
KLINE, LESTER W. Gen. Mgr. Water Dept., 106 N. San Gabriel Blvd., San Gabriel, Calif.	June 1, 1927
KNEEN, A. H. Federal Water Service Corp., 27 William St., New York, N. Y.	Jan. 8, 1911
KNICKERBACKER, JOHN, C.E. Pres. Eddy Valve Co., 86 First St., Troy, N. Y.	June 24, 1913

KNIGHT, G. WEBBER. Manager, Natrona Water Co., Natrona, Pa. .... Dec. 21, 1925
KNIGHT, GERALD W. Consulting Sanitary Engineer, 147 Prospect St., Passaic, N. J. .... Nov. 25, 1925
*KNOUSE, HOMER V. Const. Engr., Metropolitan Utilities Dist., Utilities Bldg., 18th & Harney Sts., Omaha, Nebr. .. Sept. 21, 1918
*KNOWLES, CLARENCE R. Supt. Water Service, I. C. R. R., 6627 Woodlawn Ave., Chicago, Ill. .... June 4, 1913
*KNOWLES, MORRIS. Cons. Engr., 507 Westinghouse Bldg., Pittsburgh, Pa. .... July 18, 1907
KNOX, STUART K. 10 Granada Place, Montclair, N. J. .... June 8, 1909
KNOX, W. H. Asst. Engr., State Dept., of Health, Columbus, Ohio .... Jan. 17, 1927
KOHOUT, FREDERICK E. Supt., Short Hills Water Co., P. O. Box 291, Short Hills, N. J. .... Aug. 1, 1923
KOLB, JOHN KARL. Mgr., Elect. & Pump Dept., Fairbanks-Morse & Co., 630 W. Bay St., Jacksonville, Fla. .... Mar. 31, 1927
KOON, RAY EMERSON. Stevens & Koon, Cons. Engrs., Spalding Bldg., Portland, Ore. .... Feb. 11, 1922
KORSCHEN, JOHN A. Commissioner of Public Works, City Hall, Middletown, N. Y. .... Feb. 18, 1925
KOSTER, ROY F. Hyd. Engr., Western Pipe & Steel Co., 5717 Santa Fe Ave., Los Angeles, Calif. .... Aug. 30, 1927
KRAMER, WARREN A. Chemist, Water Purification Works, 236 W. 8th Ave., Columbus, Ohio .... Mar. 29, 1927
KRIEGSHEIM, HEINRICH. The Permutit Co., 440 Fourth Ave., New York, N. Y. .... May 11, 1915
KUESTER, JOHN H. Supt. Water Works, 370 Naymut St., Menasha, Wis. .... June 30, 1923
KUNIGK, W. A. Supt. & Engr. Water Works, 3201 North 20th St., Tacoma, Wash. .... Aug. 27, 1924
KUNKLE, CHARLES W. Supt. Johnstown Water Co., 229 Mifflin St., Johnstown, Pa. .... June 11, 1924
KUNZ, S. F. Chf. Operator, Filter Plant, Water Dept., R. F. D., 6, Emporia, Kansas .... Feb. 18, 1927

LAASE, WILLIAM F. 215 Myrtle Ave., Flushing, N. Y. .... May 28, 1924
*LABOON, JOHN F. Cons. Engr., 346 Bowerhill Road, Pittsburgh, Pa. .... May 23, 1923
LACOUNT, H. O. Manager, Inspn. Dept. Factory Mutual Ins. Co., 124 College Ave., West Somerville, Mass. .... May 12, 1908
LAFLIN, ALBERT A. Supt. Water Works, St. Stephen, N. B., Can .... June 10, 1920
*LAFRENIERE, THEO. J. San. Engr., Board of Health of P. Q., 59 Notre Dame East, Montreal, Canada .... June 24, 1916
LAMBERT, URBAN S. President, Alexandria Water Co., Alexandria, Va. .... Dec. 20, 1923
LAMEY, FRANK T. Supt. New Chester Water Co., 422 East 20th St., Chester, Pa. .... May 11, 1921
LANCTOT, THEO. City Engineer, Hull, P. Q., Canada .... Mar. 16, 1926
LANDRETH, C. P. President, Direct Oxidation Process Co., N. W. Cor. 17th & Lehigh Ave., Philadelphia, Pa. .... Jan. 6, 1926
LANE, FRED W. Superintendent Water Works, 1132 Locust St., St. Petersburg, Fla. .... Oct. 7, 1925
*LANGLIER, WILFRED F. Assoc. Prof. San. Eng., Univ. of California, Berkeley, Calif. .... Feb. 28, 1923
LANPHER, E. E. Managing Engr., Bureau of Water, 416 City-County Bldg., Pittsburgh, Pa. .... Apr. 8, 1922
LAPOLT, HAROLD S. Deputy Collector, Water Dept., City Hall, Middletown, N. Y. .... Feb. 14, 1925

LARMON, FRANK P. Consulting Engineer, Fort Pierce, Fla..	Apr. 17, 1914
LASSITER, LEROY IRVING. Sanitary Engineer, Consolidated Board of Health, Wilmington, N. C.	May 25, 1926
LASSO, ALFREDO F. Ing. Civ., Obras Sanitarias de la Nacion, Buenos Aires, R. Argentina.	Sept. 26, 1917
*LATHROPE, THOMAS R. Asst. Sanitary Engineer, State Dept. of Health, Columbus, Ohio	Jan. 10, 1925
LAUNER, NELSON M. Superintendent, P. O. Box 117, La Habra, Calif.	Nov. 15, 1926
LAURIE, EDWARD. Laurie Engine Company, New Birks Bldg., Montreal, Can.	June 21, 1920
*LAUTER, CARL J. Chief Chemist, Washington Filtration Plant, McMillan Park, Washington, D. C.	Apr. 13, 1922
LAUTZ, MARTIN W. Civil Engineer, 64 Inwood Place, Buffalo, N. Y.	Mar. 27, 1926
LAUTZ, W. E. Secy. and Mgr., Pekin Water Works, Pekin, Ill.	Nov. 14, 1915
LAUX, PAUL C. Chemical Representative, National Lime Association, 35 South Monroe Ave., Columbus, Ohio	Feb. 8, 1926
LAWLOR, FRANCIS D. H. Supt. Citizens Water Co., Burlington, Iowa.	July 10, 1906
*LAWRENCE, E. A. Cons. Civ. & Munic. Engr., 511-12 Hartman Bldg., Columbus, Ohio.	Apr. 6, 1921
*LAWRENCE, FREDERICK H. 145 W. Sharpnack St., German town, Philadelphia, Pa.	Mar. 5, 1924
LAWRENCE, W. H. Supt. Water Works, Box 362, Kelispell, Mont	Dec. 16, 1919
LAWRENCE, WILLARD C. Supt. Filtration & Sewage Disposal, Baldwin Filters, Fairmount Road, Cleveland, Ohio.	June 17, 1926
LAWTON, RALPH W. 137 No. Van Ness Ave., Los Angeles, Calif.	July 10, 1906
LEA, WILLIAM S. Consulting Engineer, 340 University St., Montreal, Canada.	Jan. 26, 1924
LEAHY, THOMAS J. 546 Emerson St., Denver, Colo.	July 29, 1925
LEARNED, ALBERT P. Asst. Engr., Black & Veatch, 701 Mutual Bldg., Kansas City, Mo.	May 15, 1922
LEBOLD, GEORGE. Supt. of Meters, Hackensack Water Co., 624 Park Ave., Weehawken, N. J.	Mar. 13, 1925
LEDDEN, ERNEST M. 404 Fourth Ave., New York, N. Y.	Apr. 5, 1912
LEDOUX, J. W. Cons. Engr., 112 N. Broad St., Philadelphia, Pa.	July 18, 1907
LEE, CHARLES H. Cons. Hyd. Engr., 58 Sutter St., San Francisco, Calif.	Mar. 21, 1912
LEE, SCOTT M. Supt. City Water Dept., City Hall, Arcadia, Calif.	June 6, 1927
LEET, J. N. Supt. Water Dept., North East, Pa.	May 4, 1911
LEISEN, THEODORE A. Gen. Mgr. Metropolitan Utilities Dist., Utilities Bldg., Harney at 18th, Omaha, Nebr.	June 7, 1904
LENDALL, HARRY N. Engineering Dept., Rutgers Coll., New Brunswick, N. J.	Mar. 6, 1923
LENHARDT, LAWRENCE G. Division of Engineering, Dept. of Water Supply, Water Works Park, Detroit, Mich.	June 10, 1920
LENNON, EDWARD J. Supt. Water Works Dept., City Hall, Fort Wayne, Ind.	Apr. 10, 1926
LEONARD, W. D. Manager, Water, Light & Gas Plants, 101 N. Main St., Fort Atkinson, Wis.	July 21, 1922
LEOPOLD, F. B. 407 House Bldg., Pittsburgh, Pa.	May 11, 1914
LEOVITT, W. F. Superintendent of Construction, Fresno City Water Corp., 1423 Weldon Ave., Fresno, Calif.	Mar. 16, 1927

LeSage, Thomas William. Engr., Water Works Dept., City Hall, Montreal, Canada.......... Apr. 24, 1916
Leslie, James. Canada Fire Udtrs. Assn., Coristine Bldg., Montreal, Canada.......... May 5, 1920
Lessard, C. Camille, C.E. 32 Boulevard des Allies, Quebec, Canada.......... Feb. 25, 1927
*Letton, H. P. Grant, Fulton & Letton, Engrs., 525 South 13th St., Lincoln, Nebr.......... Dec. 23, 1914
Levering, George S. Hydraulic Engr., Bureau of Water, City Hall, Philadelphia, Pa.......... May 24, 1922
*Levine, Dr. Max. Assoc. Prof. Bacteriology, Iowa State College, Ames, Iowa.......... Nov. 30, 1921
Levy, A. G. Engr. Construc. & Surveys, Div. of Water, 9405 Hough Ave., Cleveland, Ohio.......... May 17, 1910
Lewis, Chester F. Cons. Engr., c/o Spoon & Lewis, Box 990, Greensboro, N. C.......... Apr. 23, 1924
Lewis, John V. 67 Normandy Ave., Rochester, N. Y.......... Feb. 18, 1921
*Libby, Frank D. Chemist, Kalamazoo Vegt. Parch. Co., Kalamazoo, Mich.......... May 23, 1923
Lilly, H. Albert. Chemist, Aluminum Co. of America, P. O. Box 356, Badin, N. C.......... July 19, 1927
Lilly, John. Assistant Waterworks Engineer, British Municipal Waterworks, Tientsin, North China.......... Dec. 20, 1926
Linders, Ed. Engineer of Design, Water Dept., 601 City Hall, Cleveland, Ohio.......... Oct. 16, 1925
Lira, Leonardo. Chf. Engr. of Inspt. Water Works, Casilla 492, Santiago, Chile.......... Sept. 9, 1919
*Litch, M. B. Chemist in charge of Filters, 631 Pine St., Steelton, Pa.......... May 1, 1922
*Little, Beekman C. 305 Cutler Bldg., East Avenue, Rochester, N. Y.......... June 24, 1903
Lloyd, Cyrus T. 514 Main Street, New Rochelle, N. Y.......... May 29, 1925
*Lochridge, Elbert E. Engineer Water Dept., P. O. Box 1238, Springfield, Mass.......... July 10, 1906
Lock, B. W. Supt. Water & Light Dept., Box 205, Edenton, N. C.......... Dec 29, 1924
Lockwood, Wilbur D., C. E. 903 Second St., Peekskill, N. Y.......... Mar. 19, 1924
Lofton, H. M. Chattanooga, Tenn.......... May 25, 1895
Logan, C. G. Supt. Waterworks, Waynesville, N. C.......... Dec. 8, 1923
Lompley, J. H. Hendersonville, N. C.......... Aug. 28, 1926
Long, George J. Prest., Inter-State Water Co., P. O. Box 2360, Louisville, Ky.......... May 24, 1915
Long, James H. Chief Engr., City Hall, Camden, N. J.......... May 13, 1919
Longland, E. L. Supt., Municipal Water District, San Rafael, Calif.......... Apr. 10, 1924
Longley, F. F. Lock Joint Pipe Co., P. O. Box 21, Ampere, N. J.......... July 18, 1907
Lott, Erskine H. V. P. & Gen. Mgr., Flatbush Water Works Co., 785 Flatbush Ave., Brooklyn, N. Y.......... May 26, 1916
Loughran, James F. 74 John St., Kingston, N. Y.......... Jan. 19, 1926
Lounsbury, Wm. C. Gen. Mgr., Superior Water, Lt. & Pwr. Co., Superior, Wis.......... May 12, 1908
Lourie, G. E. Water Works Supt., P. O. Box 388, Bristol, Conn.......... Sept. 20, 1923
*Lovejoy, Wm. H. Supt. Filtration, Louisville Water Co., Louisville, Ky.......... June 4, 1908
Loveland, Chester H. Consulting Engineer, 908 Balboa Bldg., San Francisco, Calif.......... Oct. 22, 1924

LOVELL, A. P. Gen. Formn., San Diego Wtr. Dept., 2516 San Marcos Ave., San Diego, Calif.	Nov. 8, 1923
LOWE, ROBERT EDWARD. Murfreesboro, Tennessee.	Apr. 27, 1925
LOWER, J. R. Chemist-in-Charge, Bucyrus Water Works, Bucyrus, Ohio.	Sept. 28, 1927
LOWTHER, BURTON. Consulting Engineer, 316 Guardian Trust Bldg., Denver, Colo.	June 21, 1921
LUCE, ARTHUR T. Federal Water Service Corp., 27 William St., New York, N. Y.	Apr. 10, 1919
LUDLOW, J. L. Cons. Engr., Winston-Salem, N. C.	June 7, 1904
LUIPPOLD, G. T. Wallace & Tiernan Co., 304 Holm Bldg., 3923 W. 6th St., Los Angeles, Calif.	Feb. 16, 1924
LUNDELL, GEORGE R. Asst. Chemist & Bacteriologist, Fridley Filtration Plant, Minneapolis, Minn.	Aug. 8, 1927
LUNDBERG, ERIC. Water Works Supt., Galva, Ill.	Sept. 25, 1923
LUSCOMBE, WILLIAM. Vice Pres. Gary Heat, Light & Water Co., Gary, Ind.	May 12, 1908
LUTHY, FRED. Chf. Engr. Water Dept., Orange, N. J.	June 8, 1921
LYLE, NEWTON B. Supt. Clymer Water Co., Room 203, Savings & Trust Bldg., Indiana, Pa.	June 17, 1926
LYMAN, RICHARD R. Consulting Civil Engineer, 47 E. So. Temple St., Salt Lake City, Utah.	Dec. 18, 1924
LYNCH, THOMAS C. Supt., Rochester Water Works, Meter Dept., Dewey Ave., cor. Bloss St., Rochester, N. Y.	Feb. 17, 1927
LYON, A. S. Supt. of Public Works, Rocky Mount, N. C.	Dec. 8, 1923
LYON, FRANK A. Supt. City Water Dept., 130 East St., Oneonta, N. Y.	Oct. 16, 1924
LYON, MRS. FRANK A. Chemist & Asst. Supt., Water Department, 130 East St., Oneonta, N. Y.	Dec. 15, 1925
McADAMS, W. A. Supt. Water & Light Dept., Farmville, N. C.	Dec. 8, 1923
McALARY, ALLAN. Supt. & Treas. Camden & Rockland Water Co., Box 151, Rockland, Me.	Apr. 18, 1922
McALPINE, A. H. Genl. Western Agt., Hersey Mfg. Co., 1557 E. Long St., Columbus, Ohio.	Apr. 27, 1889
McAMIS, JAMES W. Supt., Water Works, Greeneville, Tenn.	Sept. 12, 1921
McBRIDE, W. Z. Secretary & General Manager, Vacaville Water & Power Co., Vacaville, Calif.	June 23, 1926
McBURNETT, B. B. Water Superintendent, City Hall, Chickasha, Okla.	Feb. 2, 1924
McCAFFERY, BERNARD J., M.E. Supt. of Water Works, South Bend, Ind.	Mar. 10, 1926
McCAFFREY, WM. A. Supt. Water Works, 191 E. 6th St., Oswego, N. Y.	June 21, 1920
McCALEB, WM. B. Gen. Supt. Wtr. Cos., P. R. R., Coml. Trust Bldg., Rm. 922, Philadelphia, Pa.	Sept. 30, 1919
McCALL, MALCOLM J. Chf. Engr., Ohio Valley Electric & Trans. Util., 206 Mutual Bldg., Kansas City, Mo.	June 28, 1924
McCARTHY, OWEN A. Commissioner of Water Supply, City Hall, Fordson, Mich.	Mar. 3, 1927
McCARTY, EDWARD C. California Water Service Co., 412 Hunter-Dulin Bldg., San Francisco, Calif.	July 11, 1927
McCLASKEY, GEORGE G. Consulting Engineer, 818 Renkert Building, Canton, Ohio	June 9, 1921
McCLELLAN, THOMAS D. United Piece Dye Works, Lodi, Bergen Co., N. J.	Aug. 28, 1924
McCLENAHAN, W. T. 6218 University Ave., Chicago, Ill.	Apr. 7, 1914
McCLINTOCK, JAMES R. 170 Broadway, New York, N. Y.	Jan. 12, 1914

McClure, Ira E. Supt. Water Works, P. O. Box 45, Columbus, Mont. . . . Mar. 27, 1925
*McConnell, Earle G. Mees & Mees, 616 Johnston Bldg., Charlotte, N. C. . . . June 1, 1923
*McCrady, MacHarvey. Chmst. & Bact., Bd. of Hlth. of P. Q., 59 Notre Dame East, Montreal, Canada . . . Apr. 7, 1916
McCrea, T. R. Biologist, Morehead City, N. C. . . . Aug. 28, 1926
McCrudden, D. A. Asst. to Chief, Bur. of Wtr., 796 City Hall, Philadelphia, Pa. . . . July 7, 1920
McCulloh, C. Engineer, 2320 Grand Ave., Minneapolis, Minn. . . . May 27, 1922
McCulloh, Walter. Consulting Engineer, 406 Gluck Bldg., Niagara Falls, N. Y. . . . Mar. 17, 1926
McCurdy, H. S. R. Chf. Engr., Phila. Suburban Water Co., 762 Lancaster Avenue, Bryn Mawr, Pa. . . . July 16, 1927
McCurdy, Howard. City Engineer & Supt. Water Works, 4305 Santa Fe Ave., Vernon, Calif. . . . Dec. 29, 1925
McDonald, John H. Pres. Bd. Water Comnrs., City Hall, St. Paul, Minn. . . . June 19, 1920
McDonnell, Robert E. 402 Interstate Building, Kansas City, Mo. . . . May 25, 1913
McEvoy, Edward F. 61 Winfield Ave., Jersey City, N. J. . . . May 28, 1924
McFarland, Chester R. Secy. & Gen. Mgr., Tampa Water Works Co., Tampa, Fla. . . . May 12, 1908
McFaul, W. L. Mgr. Water Dept. & City Engr., City Hall, Hamilton, Ont., Canada . . . Mar. 8, 1924
McGee, John. Tonopah, Nevada . . . May 12, 1925
McGeehin, D. J. Supt. Wyo. Valley Water Supply Co., Markle Bank Bldg., Hazleton, Pa. . . . June 11, 1916
McGonigale, Wm. J. P. O. Box 2360, Louisville, Ky. . . . Apr. 5, 1912
McInnes, F. A. Cons. Engr., 264 Bay State Rd., Boston, Mass. . . . May 12, 1914
McIntosh, William. Cons. Engr., Sir M. MacDonald & Partners, 72 Victoria St., London, S. W. 1, England . . . Feb. 26, 1913
McKaughan, O. M. Supt. Water Dept., Wake Forest, N. C. Dec. 8, 1923
McKay, John William. Boro. Engr. Mhntn. Dpt. W. S. G. and E., 170 College Ave., Boro. Rchmnd., New York. Feb. 19, 1920
McLaren, Peter. Hydraulic Engineer, 501 N. Washington Ave., Whittier, Calif. . . . Oct. 13, 1926
McLaughlin, H. L. Salesman, National Meter Co., 1117 York St., Denver, Colo. . . . Mar. 10, 1926
McLeod, J. A. Asst. Chf. Insp., Bureau of Engineering, State Board of Health, Raleigh, N. C. . . . Apr. 23, 1924
McMillan, J. A. Manager Water Works, Charlottetown, P. E. I., Can. . . . Mar. 16, 1927
McNamee, Robert L. Principal Assistant Engineer, Hoad, Decker, Shoecraft & Drury, State Sav. Bk. Bldg., Ann Arbor, Mich. . . . June 17, 1926
McNeil, J. L. Superintendent Water Works, Lumberton, N. C. . . . Aug. 28, 1926
McQueen, Leo E. Supt. Bd. Pub. Wks., Coldwater, Mich. . . . Apr. 13, 1923
McRae, John B. Cons. Engr., Jackson Bldg., Ottawa, Canada. . . . May 9, 1906
McRae, W. Percy. General Supply Co., 358–360 Sparks St., Ottawa, Canada . . . Jan. 30, 1924
McReynolds, B. B. Supt. Water Wks., City Hall, Colorado Springs, Col. . . . May 25, 1914
McRoberts, Lewis H. Regulatory Department, State of North Dakota, Bismarck, N. Dak. . . . July 31, 1924
McVea, J. C. City Engineer, City Hall, Houston, Texas. . . . Nov. 6, 1924

McWane, J. R. Pres., McWane Cast Iron Pipe Co., Birmingham, Ala. .... Feb. 26, 1926
McWilliams, D. E. Prest., Bear Gap Wtr. Co., Mgr. Roaring Creek Wtr. Co., Box 17, Shamokin, Pa. .... Mar. 16, 1922
Mabee, William Curtis. Asst. Chief Engineer, Indianapolis Water Co., 113 Monument Cir., Indianapolis, Ind. Dec. 19, 1924
Macallum, Andrew F. Comnr. of Works & City Engr., City Hall, Ottawa, Ont., Canada .... Feb. 23, 1927
MacCarty, A. City Commissioner, Box 115, Sheridan, Wyo. Feb. 18, 1925
MacDonald, Emmett. Mgr., Illinois Water Service Co., Sterling, Ill. .... June 7, 1904
MacDonald, W. B. Manager, Mountain States Power Co., Kalispell, Mont. .... Feb. 23, 1926
MacDonald, W. E. City Water Works Engineer, 21 Fourth Ave., Ottawa, Can. .... May 8, 1917
MacKall, Murray R. Hyd. Engr., California Railroad Commission, State Building, Civic Center, San Francisco, Calif. .... May 11, 1927
MacKenzie, S. H. Engr. & Supt. Terryville & Southington Water Works, Southington, Conn. .... Apr. 14, 1916
Mackie, F. G. City Engineer, North Bay, Ont., Canada... Mar. 16, 1926
Macksey, Henry V. 68 Pleasant St., Framingham Centre, Mass. .... May 28, 1924
MacNicol, N. Township Engineer, Township of Etobicoke, Islington, P. Q., Canada .... Mar. 16, 1926
Macqueen, Philip O. U. S. Engineers Office, Little Falls & Conduit Rds., Washington, D. C. .... May 28, 1924
Madison, James Talbott. Civil Engineer, P. O. Box 435, Lawrenceburg, Ky. .... Apr. 26, 1926
*Maffitt, Dale L. Chemist, Des Moines Municipal Water Plant, Des Moines, Ia. .... Apr. 2, 1918
Maffitt, Howard C. Consulting Chemist, 526—11th St., Des Moines, Iowa .... Dec. 20, 1926
Maffitt, M'Kean. Supt. Water & City Eng., Wilmington, N. C. .... Dec. 11, 1922
Magerstadt, Paul E. East Bay Water Co., 512 16th St., Oakland, Calif. .... June 23, 1922
Mahlie, Winfield S. Chst. in Chge. Filtn. Plant, Fort Worth, Texas .... Feb. 28, 1923
Mahoney, Arthur Sawyer. City Engr., 94 Washington Ave. Clifton, N. J. .... July 18, 1923
Main, Geo. A., M.E. Cons. Engr., 14 Baker St., Daytona, Fla. .... Apr. 27, 1910
*Maitland, Alexander. Cons. Engr., 1012 Baltimore Ave., Kansas City, Mo. .... May 16, 1923
Mallalieu, Capt. Willard C. Civil & Sanitary Engineer, Jersey City Water Works, Boonton, New Jersey .... Dec. 4, 1914
Manahan, Elmer G. Cons. Engrs., Fuller & McClintock, 170 Broadway, Room 1512, New York, N. Y. .... June 8, 1909
Manahan, Patrick. Supt. Water Works, Briarcliff Manor, N. Y. .... May 27, 1924
*Mangun, L. B. Chst. in Chge. of Water Purification, Kansas City, Kansas .... Feb. 23, 1920
Mansfield, Myron G. Div. Engr., Morris Knowles, Inc., 507 Westinghouse Bldg., Pittsburgh, Pa. .... June 11, 1924
Mantel, F. A. 1043 Greenlaw Ave., Memphis, Tenn. .... Mar. 5, 1924
Mapes, John B. Constr. Engr., 38 E. Post Rd., White Plains, N. Y. .... Apr. 16, 1923
Mar, Y. C., C.E. Pumping Station, Tamarind St., West Palm Beach, Fla. .... Dec. 24, 1925

*MARK, COLEMAN B. Dist. Engr. Pa. Dpt. of Hlth., 603 N. 3rd St., Harrisburg, Pa. .... May 3, 1923
MARNER, PAUL B. Hyde Park, Y. M. C. A., 1400 E. 53rd St., Chicago, Ill. .... Sept. 13, 1926
MARS, A. D., JR. Mgr., Neptune Meter Co., 1700—15th St., Denver, Colo. .... Dec. 16, 1926
*MARS, L. DONALD. Asst. San. Engr., U. S. P. H. S., Jefferson, Ore. .... June 30, 1920
*MARSDEN, RAYMOND R. Dean, Thayer School of Civil Eng., Hanover, N. H. .... Jan. 26, 1925
MARSH, FRANCIS B. 66 Woodbury St., Providence, R. I. .... May 19, 1924
MARSHALL, CYRIL E. Professional Civil Engineer, 266 Fulton Ave., Hempstead, N. Y. .... Aug. 12, 1924
MARSHALL, HUGH A. 1426 E. 65th Place, Apt. 3B, Chicago, Ill. .... Oct. 7, 1924
MARSHALL, J. B. Chf. Engr. Tucker & Laxton, Inc., 900 Realty Bldg., Charlotte, N. C. .... Nov. 8, 1923
MARSHALL, JOHN. Supt., Flagstaff Municipal Water Works, Flagstaff, Ariz. .... Sept. 29, 1925
*MARSHALL, L. A. Asst. Supt. Filtn. and Swg. Displ., Filtration Plant, Cleveland, O. .... May 26, 1921
*MARSTON, FRANK ALWYN. Metcalf & Eddy, 1300 Statler Bldg., Boston, Mass. .... Feb. 20, 1922
MARTIN, J. C. Attorney, Ohio Water Works Association, 414 Gasco Bldg., Columbus, Ohio .... May 11, 1915
MARTIN, J. T. Comnr. of Water, 1452 W. 98th St., Cleveland, O. .... Aug. 18, 1920
MARTIN, MARK. Pres., Martin & Heyn Co., 744 Omaha Natl. Bank Bldg., Omaha, Nebr. .... Mar. 10, 1926
MARTINDALE, R. W. 909 Monadnock Bldg., San Francisco, Calif. .... Nov. 8, 1923
MARVIN, GEORGE. Supt. of Water & Light Dept., Marshfield, Wis. .... Sept. 3, 1924
MARVIN, J. B. Sect. & Gen. Mgr. Frankfort Water Works Co., 259 North Jackson St., Frankfort, Ind. .... Dec. 29, 1924
*MARX, PROF. C. D. Civil Engineering, Stanford University, Cal. .... Nov. 6, 1924
MASON, S. J. Engr. & Supt. Water Works, Perth Amboy, N. J. .... May 7, 1917
MASSEY, GEORGE B. Vice Pres., Randolph Perkins Co., Cons. Engrs., Room 1444, 33 So. Clark St., Chicago, Ill. .... June 17, 1926
*MASSINK, A. Chst. & Bact., Central Laboratory of Holland, Utrecht, Holland. .... July 20, 1921
MAST, JAMES E. Civil Engr., 519 Penn St., Reading, Pa. .... Feb. 20, 1925
MASTERS, EUGENE. City Manager, St. Augustine, Fla. .... Apr. 27, 1927
MATHEWS, WILLIAM W. 842 Temple Ave., Knoxville, Tenn. .... Nov. 18, 1925
MATTE, HUBERT P. T. Coml. Engr., Worthington Pump & Machy. Corp., Harrison, N. J. .... July 26, 1913
MATTER, L. D. District Engr., 56 West Union Street, Wilkes-Barre, Pa. .... May 3, 1923
MATTESON, VICTOR ANDRE. Water Works, Architect, 1402 Hartford Bldg., Chicago, Ill. .... May 19, 1923
MATTHEWS, IRVING E. Engr., Water Works, 43 City Hall, Rochester, N. Y. .... May 25, 1919
MAUCH, THEO. C. M. Supt. Pumping Stations, Indianapolis Water Co., Indianapolis, Ind. .... Dec. 29, 1924
MAURICE, GEORGE HOLBROOKE, C.E. Eagle Springs, N. C. .... Mar. 11, 1911
*MAURY, LT. COL. DABNEY H. 1445–6–7 Monadnock Block, Chicago, Ill. .... Aug. 22, 1894

MAUZY, ANDREW B. Water Conservator, City Hall, Jersey City, N. J.	Dec. 8, 1922
MAVIS, F. THEODORE. 304 W. University Ave., Urbana, Ill.	Oct. 23, 1925
*MAXWELL, DONALD H. Prin. Asst. Engr., Alvord, Burdick & Howson, 1417 Hartford Building, Chicago, Ill.	Feb. 15, 1917
MAY, STEPHEN C. 648 Lee Street, S. W., Atlanta, Ga.	Jan. 26, 1926
MAYO, W. T. Commr. of Public Utilities, P. O. Box 284, Shreveport, La.	June 16, 1927
MAYO, WILLIAM B. c/o Ford Motor Co., Detroit, Mich.	Aug. 16, 1917
MEAD, DANIEL W., C.E. 120 W. Gorham St., Madison, Wis.	Apr. 18, 1889
*MEADOWS, JAMES O. San. Engr., 20 Charlevoix St., Montreal, Canada	June 21, 1920
MEEKER, GEORGE R. Supt. Water Works, Geneseo, N. Y.	Apr. 2, 1923
MEERBURG, DR. P. A. Central Laboratories, Sterrebosch 1, Utrecht, Holland	Feb. 16, 1924
MEES, ERICH A. Consulting Engineer, Kinney Bldg., Charlotte, N. C.	May 23, 1923
MEGRAW, WILLIAM A. Gilman Apartments, Calvert & 31st Sts., Baltimore, Md.	Apr. 24, 1921
MEINECKE, H. Aktiengesellschaft, Breslau-Carlowitz, Germany	Sept. 17, 1924
*MELLEN, ARTHUR F. Filtr. Engr., Water Wks. Dept., Box 15, St. Anthony Falls Sta., Minneapolis, Minn.	Mar. 24, 1915
MELLON, T. A. Pres. Kensington Water Co., 2112 Oliver Bldg., P. O. Box 1114, Pittsburgh, Pa.	June 24, 1903
*MENDELSOHN, ISADOR W. U. S. Public Health Service, 4141 Clarendon Ave., Chicago, Ill.	Feb. 9, 1920
MENOLD, HARRY. Supt., Water & Elec. Light Plant, Hinsdale, Ill.	May 24, 1927
MENTZ, HENRY A. Cons. Engr., Lock Drawer No. 929, Hammond, La.	Oct. 7, 1919
MERCKEL, FREDERICK G. Wallace & Tiernan Co., 180 N. Market St., Chicago, Ill.	Jan. 29, 1921
MERRILL, GEORGE FIELD, C.E. Supt. Water Works, Ware, Mass.	Apr. 16, 1920
MERRIMAN, RICHARD M. c/o Ulen & Company, Rue Acadamie 39, Athens, Greece	May 17, 1923
MERRIMAN, THADDEUS. Chf. Engr. Board of Water Supply, 2224 Municipal Bldg., New York, N. Y.	May 29, 1920
*MESSER, RICHARD. San. Engr., State Dept. of Health, 615 State Office Building, Richmond, Va.	Sept. 27, 1911
METCALF, JOHN T. Asst. Engr., in Charge L. I. Watershed, 182 Lefferts Ave., Brooklyn, N. Y.	June 7, 1916
MEYER, H. R. J. 4551 Alice Avenue, St. Louis, Mo.	Jan. 19, 1925
MEYERHERM, CHARLES F. Albert F. Ganz, Inc., 511 Fifth Ave., New York, N. Y.	Jan. 26, 1922
MEYERS, A. H. Supt., Water Co., Columbia, Pa.	June 14, 1903
MEYERS, DUDLEY C. Comr. Public Works & Supt. Water Dept., Municipal Bldg., Oak Park, Ill.	Apr. 9, 1925
MICHAEL, A. M. Superintendent of Water Wks., Mebane, N. C.	Aug. 28, 1926
MICHAELS, A. P. Gen. Mgr., Orlando Utilities Comn., Orlando, Fla.	Aug. 15, 1924
MICHAU, R. Chief Engineer, Water Works, French Concession, c/o French Tramways Co. 227 Avenue Dubail, Shanghai, China	Mar. 3, 1927
MICHIE, JOHN C., C.E. Supt., Water Works Dept., Durham, N. C.	June 24, 1903
*MICKEL, CLARENCE W. Chemist, Muscle Shoals, Ala.	Aug. 8, 1922
MILES, H. D. 712 Washington St., Utica, N. Y.	June 30, 1924

MILHOLLAND, H. CHARLES. Asst. Engr. Am. W. W. & E. Co., 50 Broad St., New York, N. Y.	Apr. 20, 1923
MILLAN, W. ED. Civil Engineer, P. O. Box 471, Mattoon, Ill.	May 14, 1926
MILLER, ARTHUR P. 117 W. Woodbine Street, Chevy Chase, Md.	Sept. 25, 1920
MILLER, CHARLES F. 73 Vermont St., Rochester, N. Y.	Apr. 10, 1926
MILLER, CLIFFORD N. Hyd. Engr., 2807 Union Central Bldg., Cincinnati, Ohio	May 13, 1915
MILLER, EDWIN E. Asst. Supt. Power Plants, Hackensack Water Co., Weehawken, N. J.	Mar. 11, 1914
*MILLER, H. E. Director Bur. San. Eng., State Bd. of Hlth., Raleigh, N. C.	May 23, 1921
MILLER, J. A. Supt. Water Works, 10 West 3rd St., Alton, Ill.	May 8, 1909
MILLER, MAURICE L. City Hall, Waukegan, Ill.	Feb. 15, 1926
MILLER, WALTER EDWARD. 1719 Madison St., Madison, Wis.	Nov. 17, 1911
MILLER, WARREN C. City Engr., City Hall, St. Thomas, Ont,, Can	Feb. 28, 1923
MILNE, ALEXANDER. Supt. Water Works, St. Catharines, Ontario, Canada	June 24, 1903
MINOR, EDWARD EASTMAN. Gen. Mgr. New Haven Water Co., New Haven, Conn.	May 20, 1912
MINOR, L. O. Supt., Water Works, Plattsmouth, Nebr.	July 8, 1922
MITCHELL, J. J. 811 Elm St., Linden, N. J.	Oct. 21, 1920
MITCHELL, LEWIS. City Waterworks Engineer, Town Hall, Bradford, England	Nov. 15, 1924
MITCHELL, NEWTON. Supt. Paris Water Co., Paris, Ky.	Jan. 7, 1924
MIXSON, J. P. Superintendent Water Works, Palmetto, Fla.	Dec. 22, 1926
MOAT, CHARLES P. Chemist, Vermont State Board of Health, 2 Colchester Ave., Burlington, Vt.	Jan. 29, 1915
MOBERG, A. R. 4044 Lyndale Ave., So., Minneapolis, Minn.	Dec. 7, 1926
*MOHLMAN, FLOYD W. Chf. Chst., San. Dst. of Chicago, 1014 South Michigan Ave., Chicago, Ill.	Oct. 22, 1921
MOHR, JACK. Superintendent Water Dept., 549½ So. Rugby Ave., Huntington Park, Calif.	June 5, 1926
MOIR, DONALD. Cia Aguas Corrientes, Calle Salta 1461, Rosario de Santa Fe, A. R.	June 25, 1924
MOLIS, WM. Supt. Water Works, Muscatine, Iowa	Mar. 15, 1882
*MONFORT, WILSON F. Consulting Chemist, 506 N. Vandeventer Ave., St. Louis, Mo.	July 10, 1906
MONROE, H. L. Supt. Water Works, Pontiac, Mich.	July 10, 1919
MONTABONE, A. J. F. Imperial Theater Bldg., Room 2, Montreal, Canada	Nov. 9, 1922
MONTGOMERY, JAMES M. Mgr., Municipal Water Works, City Hall, Piqua, Ohio	June 6, 1927
MONTOULIEU, HENRY J., C.E. Calle B, No. 70, Entre 21 y 23, Vedado, Habana, Cuba	Nov. 17, 1911
MOORE, CHARLES E. 311 Avenham Ave., Roanoke, Va.	Oct. 5, 1923
MOORE, GEORGE S. Superintendent Water & Light, Albemarle, N. C.	Apr. 23, 1924
MOORE, J. W. Cons. Engr., 836 Ind. Pythian Bldg., Indianapolis, Ind.	Feb. 9, 1925
MOORE, L. E. Supt. Water Works, 1115 St. Claire St., Port Huron, Mich.	June 8, 1921
MOORE, R. M. Secty. & Mgr., Peoples Water Co., of Palms, Calif., 1018 Trust & Savings Bldg., Los Angeles, Calif.	June 30, 1920
MOREHOUSE, WALLACE W. Director, Dept. of Water & Sewers, 20 E. 2nd St., Dayton, O.	Jan. 16, 1923
*MOREY, DAVID, JR. San. Engr., 517 Praetorian Bldg., Dallas, Texas	May 21, 1923

Morgan, Frank Leslie. "Ribbesford," Styvechale Ave., Coventry, England.......... June 30, 1926
Morgan, Henry B. Grand View Drive, Peoria, Ill.......... Apr. 24, 1910
Morlan, Wilbert. 58 S. Cottage St., Valley Stream, N. Y. May 24, 1922
Morrill, Arthur B. Asst. Engr. of Filtration, Dept. of Water Supply, Waterworks Park, Detroit, Mich....... Oct. 21, 1925
Morris, Charles H. Supervisor of Water Works, New Brunswick, N. J.......... June 7, 1916
Morris, Edward. Vice President & Manager, Central Mendocino County Power Co., Willets, Calif.......... May 28, 1926
Morris, Fred R. Sect., Appleton Water Commission, City Hall, Appleton, Wis.......... Jan. 21, 1927
Morris, J. Clyde. Director of Water, Fairmont, W. Va...... May 28, 1924
Morris, Samuel Brooks. Chf. Engr., Water Dept., 602 Central Bldg., Pasadena, Calif.......... June 10, 1920
Morrow, Ben. S. Engineer, Water Bureau, 211 City Hall, Portland, Ore.......... Apr. 13, 1926
Morrow, David C. Engineer and Superintendent, Citizens Water Company, 62 E. Wheeling St., Washington, Pa.. May 25, 1926
Morse, Howard Scott. Gen. Mgr., Indianapolis Water Company, 113 Monument Circle, Indianapolis, Ind.......... Sept. 18, 1925
*Morse, Robert B. Chf. Engr., Wash. Sub. San. Dist., Hyattsville, Md.......... Mar. 11, 1915
Moseley, Alex W., M.E. Sloan Valve Co., 4300 W. Lake St., Chicago, Ill.......... Oct. 11, 1923
*Moses, Howard E. Asst. Chf. Engr., Pa. Dept. of Health, 904 N. 2nd St., Harrisburg, Pa.......... Apr. 27, 1922
Moss, E. H. Filter Plant Operator, Weldon, N. C.......... Aug. 28, 1926
Moullet, Louis F. Assistant Office Engineer, East Bay Water Company, 2212 Blake St., Berkeley, Calif....... May 28, 1926
Moulton, George L. Consulting Engineer, 217 Alston Bldg., Tuscaloosa, Ala.......... Apr. 3, 1923
Mowrey, J. Hase. Manager of Public Utilities, 202 So. Second St., Chambersburg, Pa.......... July 20, 1925
Mudge, John Rexford. 812 Orange Grove Ave., So. Pasadena, Calif.......... May 27, 1924
Muegge, O. J. 109 West Johnson Street, Madison, Wis..... May 20, 1925
Mueller, Carl. Asst. Engr. Bureau of Water, 147 Pomona Ave., Newark, N. J.......... Apr. 25, 1923
Mullergren, Arthur L. Cons. Engr., 770 Board of Trade Bldg., Kansas City, Mo.......... Oct. 21, 1919
Mullikin, Alfred, C.E. Northeast Harbor, Me.......... Jan. 7, 1924
Mundy, Ambrose. Supt. Middlesex Water Co., Woodbridge, N. J.......... Mar. 11, 1914
Munn, Harvey T. Hyd. Engr., Natl. Board of Fire Underwriters, 209 West Jackson Boulevard, Chicago, Ill...... Mar. 9, 1920
Munro, L. A. Brunner, Mond & Co., Ltd., Northwich, Cheshire, England.......... Oct. 11, 1923
Munroe, Walter C. Savings Bank Bldg., Annapolis, Md... Jan. 30, 1924
Murphy, A. R., C.E. Fountain City, Tenn.......... Apr. 7, 1911
Murphy, Frank J. Supt. Div. of Meters, City Hall, Milwaukee, Wis.......... May 31, 1916
Murphy, Lindon J. Engineering Extension Dept., Iowa State College, Ames, Iowa.......... Jan. 10, 1927
Murray, Charles W. P. O. Box 34, Miami, Fla.......... May 30, 1925
Murray, R. M. Hydraulic & Structural Engr., 1002-A Porter Bldg., Portland, Ore.......... Feb. 11, 1922
Murrin, John A. Supt. Water Works, City Hall, Rock Island, Ill.......... June 5, 1916

Muser, E. Fred. Supt. Clear Springs Water Co., P. O. Bldg., Catasauqua, Pa. . . . . Dec. 22, 1920
Musser, H. P. Kanawha National Bank Bldg., Charleston, W. Va. . . . . Oct. 31, 1922
Myers, Richard A. Mcpl. Engr., S. E. Undwtrs. Assn., 3 W. 10th St., Charlotte, N. C. . . . . Dec. 12, 1921
Myers, Robert Harrison. Pub. Util. Mgr., Stratford, Ont. . Feb. 10, 1921
Myrtue, John J. Water Works Trustee, 615 S. 7th St., Council Bluffs, Iowa. . . . . Feb. 27, 1924

Naumann, H. T. G. City Chemist, 1024 8th St., Port Huron, Mich. . . . . Apr. 3, 1923
Nebelung, George H. Asst. Engr., Scranton Gas & Water Co., 813 Wheeler Ave., Scranton, Pa. . . . . Oct. 11, 1921
Negri, Mario L. Chf. Div. Engr., Obras Sanitarias de la Nacion, Rivadavia 2591, Buenos Aires, A. R. . . . . Nov. 24, 1926
Nelson, Fred B., C.E. 950 Woodycrest Ave., Highbridge, N. Y. . . . . July 18, 1907
Nelson, Geo. A. Supt., Water Works, City Hall, Boone, Iowa. . . . . June 6, 1927
Nelson, George I. Wallace & Tiernan Co., 605 Star Bldg., St. Louis, Mo. . . . . Mar. 21, 1923
Neville, William J. 1524 Candler Bldg., Atlanta, Ga. . . . . . Aug. 31, 1923
Nevling, J. B. Secty.-Treas. Clearfield Water Co., Clearfield, Pa. . . . . Oct. 16, 1914
Newcomb, J. P. Secretary, City Water Board, San Antonio, Texas. . . . . Jan. 30, 1926
Newcomer, Frank. Senior Engineer, with Harry O. Garman, Consulting Engr., 27 Woodland Drive, Indianapolis, Ind. . . . . Dec. 15, 1925
*Newlands, James A. San. Engr., 11 Laurel St., Hartford, Conn. . . . . Oct. 14, 1914
Newsom, Reeves J. Vice Pres., Community Water Supply Co., 46 Cedar St., New York, N. Y. . . . . Nov. 18, 1918
Nichols, E. M., C.E. 27 N. 38th St., Philadelphia, Pa. . . . . . . June 16, 1919
Nichols, Marvin C. Assistant City Engineer, Amarillo, Texas. . . . . May 26, 1925
Nicholson, Robert H. Pres. & Mgr., So. Calif. Util., Inc., 715 Sun Finance Bldg., Los Angeles, Calif. . . . . May 17, 1927
Niesley, W. M. Asst. to Sect. A. W. W. A, 170 Broadway, New York, N. Y. . . . . Apr. 30, 1924
Nimmo, John P. Supt. Water Department, 617 N. Rodney St., Helena, Mont. . . . . July 13, 1927
Nishioeda, Satoru. City Planning Bureau, Home Dpt. of the Empire, Maru-no-Uchi, Tokio, Japan. . . . . Sept. 16, 1914
Noble, Ralph E. Senior Bacteriologist, 1739 E. 67th St., Chicago, Ill. . . . . Mar. 22, 1927
Nolan, Cornelius P. Supt. Water Dept., 169 Irvington Ave., S. Orange, N. J. . . . . June 21, 1920
Nolte, August G. Sanitary Engineer, 4204a Kossuth Ave., St. Louis, Mo. . . . . Dec. 30, 1916
*Norcom, George D. San. Engr., Water Dept., Charlotte, N. C. . . . . June 10, 1921
Nordmann, Clarence F. 25 River St., Mamaroneck, N. Y. Feb. 7, 1927
Norman, Earl E. Supt. Dept. of Pub. Utilities, City Hall, Kalamazoo, Mich. . . . . Sept. 11, 1924
Norris, John Alexander. Chairman State Bd. of Water Engrs., Capitol Sta., Austin, Tex. . . . . June 16, 1919
Norris, M. Alvin. Chemist, Orlando Utilities Comm., Orlando, Fla. . . . . Feb. 10, 1927

NORTON, JOHN F. Assoc. Prof. of Bacteriology, University of Chicago, Chicago, Ill. .... May 25, 1926
NUEBLING, EDWARD. Asst. Engr., Dept. of Water Supply Gas & Elec., 1 Northern Avenue, New York, N. Y. .... Mar. 31, 1925
NUEBLING, EMIL L. Cons. Engr., 519 Penn St., Reading, Pa. May 29, 1895
NUSSBAUMER, NEWELL L. Asst. Engr. with Geo. C. Diehl, 577 Ellicott Square, Buffalo, N. Y. .... June 1, 1923
NUTT, J. A. Supt. Water Works, Monongahela, Pa. .... May 17, 1916

OBERHOLTZER, D. A. Supt. Water Dept., 133 W. Garvey Ave., Monterey Park, Calif. .... May 17, 1927
O'CONNOR, CORNELIUS J. 1904 Bathgate Ave., New York, N. Y. .... Mar. 19, 1924
*O'CONNOR, PHILLIP J. Supt. Filtration, 540 Kenilworth Rd., Warren, Ohio .... Feb. 11, 1922
ODIET, J. E. Supt. Water Department, Ronan, Montana. .... June 8, 1925
OHLIGER, L. B. Supt. Water Works, Canton, Ohio .... Nov. 12, 1919
O'LEARY, JOHN E. Pittsburgh-Des Moines Steel Co., 50 Church St., New York, N. Y. .... July 27, 1926
OLMSTEAD, CHARLES S. Supt., The Monterey Co. Water Works, Pacific Grove, Calif .... Apr. 16, 1916
OLSEN, WILLIAM C. Cons. Engineer, Box 1114, Raleigh, N. C. .... Dec. 12, 1921
OLSON, W. M. Sanitary Engineer, 737 S. Lincoln St., Chicago, Ill. .... Apr. 10, 1926
O'NEALL, A. T. Supt. Water Works, Washington C. H., Ohio .... Apr. 29, 1924
O'NEIL, PERRY. Contr. Engr., Municipal Engineering Co., 707 Pratorian Bldg., Dallas, Texas .... Mar. 20, 1922
*O'NEILL, JOHN H. Louisiana State Bd. of Health, New Orleans, La. .... Apr. 27, 1925
*ORCHARD, WILLIAM J. Sanitary Engineer, P. O. Box 178, Newark, N. J. .... Aug. 16, 1917
O'REILLY, A. R. 1337 Good Street, Reading, Penna .... May 30, 1925
ORR, ALEXANDER, C.E. Chief Engineer, Gloversville Water Works, Gloversville, N. Y. .... Aug. 7, 1909
ORR, C. A. Mgr., City Wtr. & Lt. Co., Mayfield, Ky. .... June 8, 1921
ORTIZ, HENRY. Layne-New York Co., 30 Church St., Rm. 1742, New York, N. Y. .... Mar. 16, 1926
ORTON, EDGAR. Supt. of Water Dept., City Hall, Ventura, Calif .... Nov. 6, 1924
ORTON, JAMES W. Engineering Office, Waterworks Park, Detroit, Mich. .... Mar. 6, 1926
O'SHAUGHNESSY, M. M. City Engineer, 2732 Vallejo St., San Francisco, Calif. .... July 18, 1907
OUTZEN, ANDREW N. Field Engr., Detroit City Gas Co., Detroit, Mich. .... Aug. 1, 1923
OVERSTREET, RALPH M. Supt., Henderson Water Works, 932 N. Main St., Henderson, Ky. .... Jan. 6, 1927
OWENS, ROBERTS B., B.A., B.E. Government Bdgs., Edmonton, Alberta, Canada. .... Apr. 27, 1914
OWINGS, NOBLE L. Asst. Engr. Washington Suburban San. Dist. Riverdale, Maryland. .... Jan. 4, 1923

PAIN, HERBERT. Managing Dir., Phillips & Pain, Water Sftg., 1 Rue Taitbout, Paris, France. .... Mar. 27, 1925
PAINTER, CARL ELLICOTT. V. P. & Cons. Engr., Water Works Equipment Co., Salt Lake City, Utah. .... Mar. 25, 1924
PAITOVI, ANTONIO, C.E. Rivadavia 13353, Ramos Mejia-F C. O., Buenos Aires, A. R. .... July 27, 1919

PAKES, FREDERICK L. Superintendent Water Works, Wayne, Mich. .... Feb. 23, 1926
PALMER, MARSHALL B. Engr. Bureau of Water, Syracuse, N. Y. .... May 24, 1922
PALMER, RAY S. Water Works Superintendent, Le Roy, N. Y.. Mar. 6, 1926
PALMER, RUSSELL R. Editor, "Western Waterworks," 819 Santee St., Los Angeles, Calif. .... Sept. 18, 1926
*PARKER, FRANCIS L. Ph.D., M.D., Parker Laboratory, 40 Broad St., Charleston, S. C. .... Jan. 31, 1925
PARKER, G. H. Mgr., Kentucky Actuarial Bureau, 303 Speed Bldg., Louisville, Ky. .... Feb. 23, 1924
*PARKER, HORATIO NEWTON. City Bact. & Chst., Main & Orange Sts., Jacksonville, Fla. .... June 16, 1920
PARRISH, C. A. Supt. & Manager Water Dept., Compton, Calif. .... July 23, 1923
PARSONS, CHARLES W. Republic Flow Meters Co., 2240 Diversey Parkway, Chicago, Ill. .... Apr. 2, 1923
*PARSONS, CLARK D. Assoc. Engr., Filtration Divn. Bureau of Water, Porter Ave. Pumping Sta., Buffalo, N. Y..... Apr. 11, 1922
PARSONS, L. C. Supt. Municipal Water & Lt. System, Box 636, Kings Mountain, N. C. .... July 30, 1926
*PARTRIDGE, E. M. Chf. Chemist, Paige & Jones Chemical Co., Hammond, Ind. .... Feb. 20, 1925
PASSOLT, A. A. Supt., Newnan Water & Light Commission, Newnan, Georgia .... May 12, 1925
PATE, R. L. Manager City Water Co., Springfield, Mo....... June 29, 1915
PATERSON, WILLIAM. Windsor House, Kingsway, London, England .... Nov. 6, 1924
PATITZ, G. J. 701 Washington St., New York, N. Y......... Oct. 24, 1923
PATTERSON, T. C. Superintendent Water Works, Mt. Holly, N. C. .... Dec. 8, 1923
*PATTON, W. A. Pres. & Mgr. Water Co., Catlettsburg, Ky... June 7, 1904
PATTON, W. S. Mgr. Ashland Water Works, Ashland, Ky..... May 7, 1917
PAUL, FRANK DWIGHT. Superintendent of Distribution, Akron City Water Works, 235 Crescent Drive, Akron, Ohio .... Jan. 21, 1927
PAUL, MARCEL. President, Societe Anonyme des Hauts-Fourneaux & Fonderies de Pont-a-Mousson 9-13 Rue St. Leon, Nancy, France .... Feb. 18, 1927
PAULETTE, G. W. 4929 Walrond St., Kansas City, Mo....... Feb. 18, 1927
PAULETTE, R. J. City Engineer, City Bldg., Salina, Kansas... Feb. 17, 1927
PAYES, L. W. 617 Fletcher Trust Bldg., Indianapolis, Ind... Apr. 27, 1925
PEABODY, J. R., M.D. 456 Francis Bldg., Louisville, Ky.... Dec. 29, 1924
*PEARSE, LANGDON. San. Engr., The Sanitary Dist. of Chicago, S. O. Bldg., 910 S. Michigan Ave., Chicago, Ill.. Feb. 24, 1913
PEARSON, CHARLES DEARNE. Engr. & Mgr., Wtr. Wks., Kiangse Rd., Shanghai, China .... Mar. 16, 1922
PEART, J. W. Hydro-Electric Commission of St. Thomas, St. Thomas, Ontario .... Apr. 29, 1926
PEART, JOHN. Water Supply Engineer, Metropolitan W. S. & S. Board, Brisbane, Queensland .... Sept. 12, 1910
PEASE, HERBERT D. 39 W. 38th St., New York, N. Y....... Feb. 6, 1924
PECK, ERMON M. Cons. Engr., 260 Edgewood St., Hartford, Conn. .... July 18, 1907
PECK, LAWRENCE J. District Engineer, 16 Fifth Ave., Cortland, N. Y. .... May 17, 1927
PECK, WARREN O. Dunkirk, New York .... Apr. 27, 1925
PEDERSON, H. V. Superintendent Water Works, Municipal Bldg., Marshalltown, Iowa .... Mar. 26, 1922
*PEIRCE, WALTER A. Nine Springs Sewage Disp. Wks., R.F.D. #5, Madison, Wis. .... June 15, 1922

PEIRSON, A. G. Supt., Water Power & Light Commission, Weston, Ont., Canada........ Feb. 28, 1923
PENDER, L. E. Supt. Construction & Pub. Utilities, Pinehurst N. C........ Apr. 23, 1924
PEQUEGNAT, MARCEL, B. A. Sc. Supt. Kitchener Water Comm. Kitchener, Ont........ Feb. 16, 1924
PERHAB, JOHN L. Superintendent Water Dept., P. O. Box 1333, Calexico, Calif........ May 29, 1926
PERKINS, DR. R. G. Dept. of Hygiene, W. R. U. School of Medicine, 2109 Adelbert Road, Cleveland, Ohio........ June 3, 1921
PERRY, H. W. Supt., Water Works, Box 647, Greenville, S. C........ Apr. 25, 1922
PERRY, J. ROBERT. Accountant, Municipal Water Dept., Walnut Ave., & 6th St., Niagara Falls, N. Y........ June 20, 1924
PERRY, WILLIAM. Hydraulic Engr., Maplewood Ave., Cote des Neiges, Montreal, Quebec........ June 26, 1886
PETER, W. F. Seymour, Ind........ Aug. 14, 1925
PETERS, J. S. Chf. Engr., Marin Municipal Water Dist., San Rafael, California........ Jan. 6, 1927
PETERSEN, C. O. Water Superintendent, City Hall, Brighton, Colo........ Mar. 27, 1926
PETERSON, LEONARD. Supt. Water Works, Power & Light Co., Crookston, Minn........ June 10, 1911
PHELPS, EARLE B. Prof. Sanitary Science, Columbia University, 437 West 59th St., New York, N. Y........ Oct. 19, 1914
PHILLIPS, ASA E. Box 234, Ogunquit, Maine........ Nov. 9, 1922
PHILLIPS, CHARLES J. Water Supt. & City Engr., City Hall, Puyallup, Wash........ Sept. 13, 1927
PHILLIPS, JOHN M. Nedina, New York........ July 22, 1920
PHILLIPS, LEO A. Chf. Engr., Federal Water Service Corp., 27 William St., New York, N. Y........ June 17, 1926
PIATT, WILLIAM M. Cons. Engr., Durham, N. C........ Aug. 5, 1921
PIERCE, J. F. Springdale, Pa........ Feb. 16, 1924
PIERCE, THOMAS D. Appraisal & Rate Engineer, 2487 Brentwood Road, Columbus, Ohio........ May 12, 1925
PILGRIM, HENRY E. A. Supt., Water Works, 160 College St., St. James, Man., Canada........ June 1, 1927
*PINCUS, SOL. San. Engr., 309 West 109th St., New York, N. Y........ Feb. 17, 1920
PINNELL, DR. W. R. City Bacteriologist, Lexington, Ky........ June 1, 1923
*PIRNIE, MALCOLM. Consulting Engineer, 25 W. 43rd St., New York, N. Y........ May 8, 1917
*PITCHER, F. H. G. Mgr. & Ch. Engr., Montreal W. & P. Co., Place D'Armes Square, Montreal, Canada........ June 27, 1905
*PLAMONDON, ADRIEN, C.E. Engineer & Contractor, 70 St. James St., Montreal, Canada........ May 22, 1916
PLOCH, C. E. Supt., Mt. Vernon Water Works Co., 127 Main Street, Mt. Vernon, Ind........ Jan. 27, 1925
PLUMMER, WADE. Asst. Supt., Butte Water Co., Butte, Mont. Dec. 15, 1925
POE, CHARLES F. 875—16th St., Boulder, Colo........ Sept. 24, 1926
POLGLAZE, R. A. Genl. Supt., Alabama Water Co., 624 South 54th St., Birmingham, Ala........ May 25, 1926
POLK, WESLEY W. Supt., Water Department, Sheridan Rd. & Lincoln St., Evanston, Ill........ Mar. 10, 1926
*PORT, JOHN A. Supt. Van Gilder Water Meter Co., 518 Bridgeboro St., Riverside, N. J........ May 28, 1924
*PORTER, D. P. Supt. Water Works, 1305 E. 4th St., Pueblo, Col........ Sept. 22, 1916
PORTER, JOHN LEWIS. Director, Water Purification Stations, 2142 Eagle Street, New Orleans, La........ May 12, 1925

Porter, S. J. 345 Vermont St., San Francisco, Calif........ Oct. 27, 1925
*Porzelius, A. F. Supt. City Water Co., Chattanooga, Tenn. July 7, 1920
*Potter, Alexander. Consulting Engineer, 50 Church St., New York, N. Y........ July 18, 1907
*Potts, Clyde. Civil & Sanitary Engr., 30 Church St., New York, N. Y........ July 10, 1906
Powell, Alexander C. 136 Grand Street, Bangor, Maine. Mar 12, 1910
*Powell, Sheppard T. Chemical Engineer, 4103 Hawthorne Ave., Forest Park, Baltimore, Md........ July 10, 1906
*Pracy, Geo. Wesley. Supt. Spring Valley Water Co., 425 Mason St., San Francisco, Calif........ May 18, 1915
*Pratt, Arthur H. Chf. Engr., North Jersey Dist. Wtr. Supply Comn. 20 Clinton Street, Newark, N. J........ Jan. 4, 1923
Pratt, Charles J. Supt. Water Department, City Hall, Owen Sound, Ont., Canada........ Oct. 22, 1924
*Pratt, Gilbert H. P. O. Box 178, Newark, N. J........ June 5, 1916
*Pratt, Roger W. Wallace & Tiernan Co., Inc., 223 E. 9th St., Kansas City, Mo........ Feb. 13, 1924
*Pray, John W. Supt. Water Works, Ft. Dodge, Ia........ June 24, 1913
Prince, Norman F. Chemist & Engineer, Rochester Gas & Elec. Corp., Rochester, N. Y........ Mar. 26, 1927
Prindle, George B. c/o Pearse, Greeley & Hansen, 6 North Michigan Ave., Chicago, Ill........ Mar. 25, 1924
Pringle, D. Rhett. Supt. of Water & Light Dept., Thomasville, Ga........ Sept. 27, 1924
Pringle, J. T. Supt. Stamford Water Works, Stamford Township, South end, Ont., Canada........ Apr. 28, 1925
Prinz, Robert B. Asst. Engr., Dept. of Water, Ottawa St., Dayton, Ohio........ Sept. 7, 1927
Prior, J. Murray. Board of Water Supply, Room 710, 100 State St., Albany, N. Y........ Apr. 10, 1924
Prior, John C. Prof. of Sanitary Engineering, Brown Hall, Ohio State Univ., Columbus, Ohio........ Oct. 13, 1926
Pritchard, John C. Director of Public Utilities, 312 City Hall, St. Louis, Mo........ Feb. 8, 1926
Probst, Rudolph. Superintendent Butte Water Co., Butte, Mont........ Dec. 15, 1925
Proctor, Edward M. Cons. Engr., 177 Inglewood Drive, Toronto 5, Ont., Canada........ May 5, 1921
Prokofieff, S. T. Executive Engineer, Drainage & Water Works, Gwalior, India........ Oct. 27, 1922
*Provost, Andrew J., Jr. San. Expert & Hyd. Eng., 39–41 West 38th St., New York City........ May 12, 1908
Pruett, G. C., C.E. Virginia, Minn........ Feb. 2, 1914
Prugh, J. I. Supt. Division of Water, City Hall, Sacramento, Calif........ Nov. 8, 1923
Pugh, Marshall R., C.E. 230 Poplar Ave., Wayne, Pa........ Apr. 8, 1905
Purser, J. R. Mechanical Engineer, 406 Commercial Bldg., Charlotte, N. C........ Dec. 29, 1924
Putnam, George W. 7057 Oriole Ave., Chicago, Ill........ June 15, 1922

Quayle, LeRoy A. Chf. Mech. Engr., Utilities Dept., 1440 W. 98th St., Cleveland, Ohio........ Feb. 24, 1925
Quigley, Lewis A. Supt., City Water Works, 2626 Travis, Fort Worth, Texas........ June 6, 1927
Quince, S. F. Supt. of Water Works, Borough of Sussex, N. J........ Jan. 6, 1927
Quinnell, Fred. Comnr. Public Works, Bx. 684, Roundup, Mont........ Feb. 7, 1922

*Raab, Frank. Chst. & Bact. Fridley Filtration Plant, Minneapolis, Minn. .... Oct. 26, 1921
*Race, Joseph. Devonshire Hospital, Buxton, England ..... May 18, 1914
Radcliffe, John L. Supt. Filtn., 663 Madison Ave., Elizabeth, N. J. .... Feb. 19, 1920
Rader, R. P. Sup., Lehigh Water Co., Easton, Pa. .... May 12, 1908
Ramey, H. P. Asst. Chf. Engr., Sanitary District of Chicago, 910 So. Michigan Ave., Chicago, Ill. .... June 6, 1927
Randlett, Fred Morse. Robert W. Hunt Co., 251 Kearny St., San Francisco, Calif. .... June 16, 1920
Randolph, Bud A. City Health Department, Houston, Tex. . Mar. 13, 1925
*Rapp, W. M. Supt. Const. Water Dept., P. O. Box 584, Atlanta, Ga. .... May 17, 1899
Rasch, Henry B., Jr. Junior Assistant Engineer, State Board of Health, Richmond, Va. .... Nov. 29, 1926
*Rassier, Christian C. Supt., Water Works, 330 W. Coal St., Shenandoah, Pa. .... May 24, 1922
Rathbun, W. S. Natl. Bd. of Fire Underwriters, 209 W. Jackson Blvd., Chicago, Ill. .... Apr. 13, 1922
Rawson, David P. Superintendent of Maintenance, Bloomfield, N. J. .... Dec. 31, 1925
Ray, Chas. E., Jr. Asst. Engr., Dept. of Conservation & Development Water Resources Division, Chapel Hill, N. C. .... Aug. 28, 1926
*Raymond, George B. Supt. Water Dept., Danbury, Conn. June 16, 1919
*Reber, Harry C. Pres., Angelica Water & Ice Co., 1907 Perkiomen Ave., Reading, Pa. .... Aug. 20, 1924
*Redfern, W. Blaine. Sec. Treas. James, Proctor & Redfern, Cons. Engs., 115 High Park Ave., Toronto, Ont. .... Nov. 12, 1919
Reed, D. A. Mgr. Water and Light Dept., Duluth, Minn. .... Sept. 20, 1913
Reed, George W. 2625 Budlong Ave., Los Angeles, Calif. .. July 23, 1925
Reeder, Arthur L. 25 N. Eleventh St., Reading, Pa. ...... Nov. 30, 1926
*Reeves, O. Lee. Supt., Water Works Co., 26 South Jackson St., Greencastle, Ind. .... May 24, 1922
*Reichardt, Walter Frederick. 109 Main St., Watertown, Wis. .... May 26, 1925
*Reid, Walter. Supt., Water Works, Springfield, Ill. .... May 24, 1922
Reilly, Thomas William. Supt., Pequannock Watershed, Charlotteburg, Passaic Co., N. J. .... Mar. 17, 1925
Reinhardt, Harry. Asst. Chf. Engr., East Bay Water Co., Oakland, Cal. .... Apr. 12, 1921
Reinke, Edward A. 102 C. E. Bldg., Berkeley, California... Nov. 8, 1923
Reisweber, Alex. G. Asst. Engr., Western New York Water Co., 704 Electric Bldg., Buffalo, N. Y. .... Jan. 20, 1921
Relph, O. S. Superintendent Water Works, San Jose, Calif. .. Oct. 27, 1925
Requardt, Gustav J., C.E. 1828 Munsey Bldg., Baltimore, Md. .... May 17, 1923
Reyer, George. Supt. Water Works, Nashville, Tenn. ..... Apr. 16, 1884
Reynolds, Edwin G., Jr., C.E. New Rochelle Water Co., 514 Main St., New Rochelle, N. Y. .... Feb. 26, 1921
Reynolds, James H. Supt., Water Works, Lowell, Mass. May 28, 1924
Reynolds, Myron B. Asst., City Engineer, 402 City Hall, Chicago, Ill. .... Apr. 10, 1926
Reynolds, Otto S. Water Works Engineer, 918 Armour Blvd., Kansas City, Mo. .... Aug. 5, 1927
Reynolds, Ralph W. Supt., West Palm Beach Water Co., Drawer B-25, West Palm Beach, Fla. .... Nov. 15, 1926
Rhoads, A. L. Supt., W. Va. Water Service Co., Bluefield, W. Va. .... May 25, 1926
Rhodes, C. I. 820 Colusa Ave., Berkeley, Calif. .... Oct. 22, 1924

Rhyne, C. E. Supt. Water Works, Gastonia, N. C. .... Jan. 17, 1922
Rhynus, C. P. 122 East Par Ave., Orlando, Fla. .... May 14, 1912
Rice, Clifton L. P. O. Box A 45,, West Palm Beach, Fla... July 7, 1920
Rice, Cyrus Wm. 617 Highland Bldg., Pittsburgh, Pa. .... Oct. 5, 1924
Rice, John M. Cons. Engr., 411 Oliver Bldg., Pittsburgh, Pa. June 8, 1921
Rice, Lawrence G. Messrs. Fuller & McClintock, 170 Broadway, New York, N. Y. .... Feb. 23, 1924
Rice, P. D. Sweetwater, Water Corp., National City, Calif... Nov. 15, 1926
Richards, W. J. President, Phila. & Reading Coal & Iron Co., 200 Mahantongo St., P. O. Box 272, Pottsville, Pa. .... Dec. 10, 1925
Richards, Walter A. City Manager, Daytona Beach, Fla. Mar. 10, 1926
Richardson, Charles G. Sales Mgr., c/o Builders Iron Foundry, Providence, R. I. .... July 7, 1920
Richardson, H. H. Engr. Wtr. Svce., Mo. Pac. R. R., 1055 Ry. Exc. Bldg., St. Louis, Mo. .... Aug. 23, 1920
Rickard, Grover E. Chemist & Supt. of Filtration, 1909 Warwood Ave., Wheeling, W. Va. .... June 5, 1926
Rider, Earl L. Supt., Crescenta Mutual Water Co., Box 54, Verdugo City, Calif. .... Oct. 29, 1926
Rider, Jane H. Dctr. Ariz. State Laboratory, Tucson, Ariz.. Aug. 23, 1920
Ridley, Clarence Eugene. School of Citizenship and Public Affairs, Syracuse University, Syracuse, N. Y. .... Dec. 5, 1918
Riebel, Thomas S. Supt. Queen Lane Filters, 942 E. Price St., Philadelphia, Pa. .... May 28, 1924
Riffee, George A. Supt. Shinnston Water Board, Shinnston, W. Va. .... Jan. 30, 1924
Rigney, T. A. Laurel, Montana .... May 26, 1925
Riley, Chas. R. Asst. Supt. Norwich Water Works, 7 Northrup Ave., Norwich, N. Y. .... June 17, 1926
Ringness, Henry. Supt. of Accts., Peoria Water Works Co., 105 N. Monroe St., Peoria, Ill. .... Sept. 8, 1919
Ristine, G. W., Jr. Secy. & Treas., Shankland, Ristine & Co., 410 Boston Bldg., Denver, Colo .... May 12, 1925
Ritchie, Edgar Gowar. Engineer of Water Supply, Metropolitan Board of Works, Melbourne, Australia .... Sept. 6, 1912
Roach, J. R. 606 E. Green St., High Point, N. C. .... May 14, 1926
Roads, George M., Jr. Supt., Panther Valley Water Co., Edgemont, Lansford, Pa. .... Oct. 22, 1926
Robbins, W. D. City Mgr., City Hall, Niagara Falls, N. Y. Feb. 23, 1926
Roberts, Alfred M. V. P. & Mgr., Wanakoh Water Co., 132 Bedford Ave., Buffalo, N. Y. .... July 20, 1925
Roberts, Earl I. 1601 Second National Bank Bldg., Toledo, Ohio .... Jan. 11, 1918
Roberts, John S., Jr. Borough Engr., Bristol, Pa. .... June 19, 1920
Roberts, William J. Cons. Engr., 616 Puget Sound Bank Bldg., Tacoma, Wash. .... Oct. 19, 1914
Robertson, John T. Engr., Consolidated Water Co., 712 Washington St., Utica, N. Y. .... Mar. 26, 1927
Robinson, Delbert W. General Foreman, Water Co., Box 3113, West Palm Beach, Fla. .... Apr. 23, 1927
Robinson, Leonard C. Supt. Water and Sewer Dept., Concord, Mass. .... July 18, 1907
Robinson, W. W. Supt. & C.E., Russell Manufacturing Co., Alexander City, Ala. .... Mar. 31, 1924
Robinson, William P. 1700 East 3rd Ave., Denver, Colo... June 8, 1897
Robles, Gonzalo. Gerente, Torreon Water Works, Rodriguez Sur 10, Torreon, Coah, Mexico .... June 6, 1927
Roen, O. S. City Service Manager, City Hall, Ontario, Calif. Oct. 18, 1923
Rogers, M. W. Engineer, Public Utility Commission, Box 413, Carleton Place, Ont., Canada .... Mar. 16, 1927

ROGERS, T. M. Supt., City Water & Light Plant, Easley, S. C.	May 31, 1927
ROHRBACH, WM. R. Mgr. Sunbury Water Co., Sunbury, Pa.	July 10, 1906
ROLFSON, ORVILLE. Civil Engineer, Imperial Bldg., Walkerville, Ont., Canada	Dec. 24, 1925
ROMIG, C. O. Secty. and Supt. Water Supply Co., Dennison, O.	Oct. 23, 1917
ROOS, CHARLES M. Secty. and Supt. Cairo Water Co., Cairo, Ill.	May 18, 1913
ROPER, ROSWELL M. Engr., Bd. of Water Comnrs., East Orange, N. J.	May 10, 1919
ROSENTHAL, HELMAN. 2906 Peabody Ave., Dallas, Texas	June 3, 1918
ROSENTRETER, HERMAN. Engr. of Water Supply, City Hall, Newark, N. J.	Mar. 12, 1908
ROSKELLEY, C. O. Civil Engineer, Brigham City, Utah	Feb. 20, 1924
ROSSITER, EDGAR A., C.E., Burnham Bldg., Suite 1729, 160 W. Randolph Street, Chicago, Ill.	Oct. 14, 1918
ROSSMAN, JOHN D. Supt., Harvey Water Dept., 15800 Halsted Street, Harvey, Ill.	June 6, 1927
ROUTH, JAMES W. Bureau of Municipal Research, Athletic Club Building, St. Paul, Minn.	June 4, 1920
ROUTLEDGE, GEORGE GRAHAM. Supt. Water Distb. Section, 332 St. Clair Ave., E., Toronto, Ont.	Mar. 18, 1919
ROWE, E. A. 543 Petroleum Securities Bldg., 714 W. 10th St., Los Angeles, Calif.	Nov. 9, 1922
ROWE, E. J. Supt. Water & Light Dept., Wellsville, N. Y.	June 3, 1921
ROWE, LLEWELLYN H. Water Works Engineer, Box 123, Opa Locka, Fla.	Apr. 23, 1927
RUCHHOFT, C. C. 1014 S. Michigan Ave., Chicago, Ill.	June 16, 1925
RUDD, WILLIAM C. Dept. of Water Supply, Div. of Eng., Water Works Park, Detroit, Mich.	June 14, 1923
RUDDEROW, MAURICE B. Mgr. Merchantville-Pensauken Water Co., 13 W. Maple Ave., Merchantville, N. J.	June 23, 1914
RUE, J. A. Water Engr., Cent. Ill. Pub. Service Co., 1217 Marshall Ave., Mattoon, Ill.	Apr. 7, 1916
RUGGLES, A. V. Special Representative, U. S. Cast Iron Pipe & Fdy. Co., 1329 E. 110th St., Cleveland, Ohio	Aug. 16, 1920
RUPP, DANIEL H. Water Department, City Hall, Oklahoma City, Okla.	Oct. 14, 1922
RUSSELL, ALEXANDER. Sect. & Treas., Rochester & Lake Ontario Water Co., 440 Powers Bldg. Rochester, N. Y.	Sept. 21, 1927
*RUSSELL, BRINTON. Supt. Water Co., Norristown, Pa.	May 23, 1923
RUSSELL, CECIL B. Instructor in Engineering, Norristown, Pa.	June 17, 1926
RUSSELL, CHARLES S. Chf. Engr., Opa Locks Co., Inc., Box 1, Opa Locka, Fla.	Apr. 23, 1927
*RUSSELL, D. A. Chief Chemist, Youngstown Sheet & Tube Co., Youngstown, Ohio	May 31, 1924
RUSSELL, GEORGE F. Supt. Water Works, Seattle, Wash.	Mar. 27, 1925
RUSSELL, NORMAN F. S. Drawer 306, Burlington, N. J.	Dec. 10, 1915
RUTH, EDWARD D. Supt., Water Dept., City Hall, Lancaster, Pa.	May 1, 1922
RYLE, JOHN. Asst. Engr. Passaic Water Co., 158 Ellison St., Paterson, N. J.	Dec. 3, 1919
*SACKETT, ROBERT L. Dean, School of Engineering, Pa. State College, State College, Pa.	Nov. 21, 1912
SAFFORD, ARTHUR T. Engr., Proprietors Locks & Canals, 66 Broadway, Lowell, Mass.	Feb. 4, 1921

SALISBURY, J. W. Civil Engineer, Chinchilla, Lackawanna Co., Pa. .... June 13, 1924
SALMOND, JAMES J. Manager *Canadian Engineer*, 62 Church St., Toronto, Ont., Can. .... July 18, 1907
SAMPLE, J. D. Vice Pres., McWane Cast Iron Pipe Co., Birmingham, Ala. .... Feb. 26, 1926
SANBORN, JAMES F. Consulting Engineer, 30 Church St., Rm. 414, New York, N. Y. .... Aug. 22, 1921
*SANDERSON, A. U. Supt. Toronto Filtn. Plant, Foot of John St., Toronto, Canada. .... June 9, 1920
SANDQUIST, EMIL. City Engineer, Havre, Mont. .... Jan. 17, 1927
SAUNDERS, WM. E., E.M. Librarian, United Gas Improvement Co., Broad & Arch Sts., Philadelphia, Pa. .... July 26, 1919
SAURBREY, KAY N. G. 109 E. Mary St., Valdosta, Ga. .... June 28, 1926
*SAVILLE, CALEB MILLS. Mgr. & Chf. Engr. Water Works, 53 North Beacon St., Hartford, Conn. .... Mar. 18, 1916
*SAVILLE, THORNDIKE. Box 352, Chapel Hill, N. C. .... Aug. 30, 1920
SAWAI, JUNICHI. 128 Kobashi Motomachi, Higashiku Osaka, Japan .... July 21, 1919
*SAWIN, LUTHER R. Bacteriologist in Charge of Mt. Kisco Laboratory, Mt. Kisco, N. Y. .... July 14, 1916
*SAWYER, CHARLES L. County San. Engr. & Surveyor, Court House, Toledo, Ohio .... May 12, 1925
SAYER, FRED D. Supt., Brookville Borough Water Dept., Brookville, Pa. .... Apr. 22, 1914
SCARTH, STANILAND. Supt. of Water, Light & Power, Fairport, N. Y. .... Aug. 9, 1916
SCHANTZ, P. T. Supt. Highland Water Works, Co., Highland, N. Y. .... May 25, 1926
*SCHAUT, GEORGE G. 925 W. Susquehanna Ave., Philadelphia, Pa. .... Oct. 23, 1922
SCHEFFER, LOUIS K. Asst. Engr. San. Engineering, 1013 Green St., Harrisburg, Pa. .... Jan. 26, 1924
SCHERER, FREDERICK G. Asst. Engr. Bureau of Water, City Hall, Newark, N. J. .... Dec. 26, 1919
SCHIEDEL, C. W. Secy.-Treas. & Genl. Mgr. Water & Light Comn., Waterloo, Ont., Can. .... Apr. 26, 1921
SCHLICHT, JOHN C. Supt. of Pipe System, Hackensack Water Co., 624 Park Ave., Weehawken, N. J. .... June 15, 1926
SCHMID, T., JR. Jr. Sanitary Engineer, 10856 Wabash Ave., Chicago, Ill. .... Apr. 16, 1926
SCHMIDT, KARL C. 3800 12th Ave., So., Minneapolis, Minn. .... Aug. 8, 1925
SCHMIT, JOS. M. City Engineer & Water Works Supt., P. O. Box 931, Lewistown, Mont. .... Apr. 10, 1926
SCHMITT, CHARLES F. Engr. of Distribution, Water Dept., 1688 E. 84th St., Cleveland, Ohio .... June 17, 1926
SCHNABEL, WILLIAM R., C.E. Engineer Bureau of Water, 242 S. Madison St., Allentown, Pa. .... Apr. 10, 1924
SCHNEIDER, ERNST J. Supt., City Street & Water Dept., Cedarburg, Wis. .... July 30, 1925
SCHNEIDER, GEORGE. Supt., Monroe City Water Dept., 125 W. Russell Street, Monroe, Wisc. .... June 16, 1925
SCHNEIDER, WILLIAM J. Gen. Mgr., Bettendorf Water Co., Bettendorf, Iowa .... Nov. 24, 1924
SCHOLZ, ROBERT O. Senior Engr. Division of Water, 45 Seymour Ave., Newark, N. J. .... Feb. 19, 1916
SCHONERT, CHAS. O. Supt. Water Works, Hammond Water Department, Hammond, Ind. .... May 28, 1926
SCHOONMAKER, GEORGE N. 1609 North Erie St., Toledo, Ohio .... Aug. 22, 1921

SCHROEDER, E. C. Manager, Water Works Plant, 617 N. 10th St., Manitowoc, Wis. .... Aug. 26, 1924
SCHROEDER, R. C. Supt., The Consolidated Water Supply Co., 79 N. Main Street, Carbondale, Pa. .... June 17, 1926
SCHUCK, H. W. Supt., Water Department, 804 Bayswater Avenue, Burlingame, Calif. .... June 6, 1927
SCHUMPERT, HOMER W. P. O. Box 333, Newberry, S. C. .... Aug. 24, 1925
SCHUYLER, PHILIP. Editor, "Western Construction News," 114 Sansome St., San Francisco, Calif. .... Mar. 6, 1926
SCHWABE, WALTER P. P. & M. The Thompsonville Water Co., 15 Central St., Thompsonville, Conn. .... Nov. 3, 1914
SCHWABEL, FRANK. Supt., Gas & Water Depts., Clearwater, Fla. .... Mar. 31, 1927
SCHWADA, JOSEPH P. City Engineer, 923 49th St., Milwaukee, Wis. .... May 28, 1924
SCHWARZ, EUGENE. Supt., City Water Dept., Rochester, Minn. .... June 6, 1927
SCHWIER, ELMER C. Auditor, Indianapolis Water Co., 113 Monument Circle, Indianapolis, Ind. .... Dec. 29, 1924
SCOFIELD, C. L. Canadian Fire Und. Assn., 524 Coristine Bldg., Montreal, Canada .... Apr. 22, 1920
*SCOTT, J. SHELDON. Chst. in Chge. Purification Plant., 1623 State St., Steubenville, Ohio .... Nov. 27, 1920
SCOTT, ROSSITER, S., M. E. With Nicholas S. Hill, Jr., 112 E. 19th St., New York, N. Y. .... Mar. 4, 1922
SCOTT, WALTER M. Chrmn. of Comnrs., Greater Winnipeg Wtr. Dist., New Civic Offices, Winnipeg, Manitoba, Can. .... Mar. 11, 1914
SCOTT, WARREN J. Director, Bureau of Sanitary Engineering, Conn. State Dept. of Health, Hartford, Conn. .... Oct. 14, 1922
*SEERY, FRANCIS J. Prof. Hyd. Eng., Cornell Univ., 504 University Ave., Ithaca, N. Y. .... Nov. 3, 1919
SEIBERT, JOSEPH. Supt. Water Works, St. Cloud, Minn. .... June 5, 1912
SELIGMAN, FELIX. Pump Station, Duluth, W. & L. Dept., Lakewood, Minn. .... June 11, 1924
SENIOR, SAMUEL PALMER. Pres. & Engr. Bridgeport Hyd. Co., Bridgeport, Conn. .... July 10, 1906
SENSEMAN, H. L. Supt., Water Department, Box 604, Iron Mountain, Mich. .... May 24, 1927
SERKES, MEYER. 1324 Goodfellow Ave., St. Louis, Mo. .... May 25, 1926
SEVIER, ROSCOE. Asst. Sect., Los Angeles County Water Works, Gardena, Cal. .... Sept. 16, 1927
SHARON, JOHN J. Spring Valley Water Co., 425 Mason Street, San Francisco, Calif. .... Feb. 10, 1920
SHARP, A. S. Mgr. & Sect., Leadville Water Co., 719 Harrison Ave., Leadville, Colo. .... Mar. 24, 1926
SHAW, A. W. Engineer, Box 1516, Brandon, Manitoba, Can. .... Jan. 17, 1911
SHAW, C. M. Supt., Water Works, P. O. Box 822, Prescott, Arizona .... Apr. 18, 1922
SHAW, HARRY B. Asst. Engr., Washington Subn. San. Dist., Hyattsville, Md. .... Apr. 2, 1923
SHAW, WALTER A. State Public Utilities, 1509 Farwell Ave., Chicago, Ill. .... July 10, 1906
SHEAL, ROBERT E. Cons. Engineer, 2101 East 100th St., Cleveland, Ohio .... June 13, 1921
*SHELL, R. G. Supt. Filtration Plant, R. F. D. No. 4, Fayetteville, N. C. .... June 11, 1924
SHEPARD, GEORGE M. Chief Engr. Dept. Public Works, City Hall, St. Paul, Minn. .... Nov. 12, 1920
SHERMAN, ARTHUR L. 20 Clinton St., Newark, N. J. .... Feb. 16, 1924

SHERMAN, CHARLES W. Metcalf & Eddy, 1300 Statler Bldg., Boston, Mass.	May 14, 1914
SHERMAN, LEROY K. Pres., Randolph-Perkins Co., 1444 First National Bank Bldg., Chicago, Ill.	Sept. 10, 1924
SHERMAN, WALTER J., C.E. The W. J. Sherman Co., Toledo, Ohio	May 12, 1908
SHERRERD, MORRIS R. Cons. Engr., Dept. Street & Public Improvts., City Hall, Newark, N. J.	June 7, 1897
SHIBLEY, KENNETH. Manager, California Filter Co., 202 Securities Bldg., Seattle, Wash.	Sept. 1, 1915
SHIELDS, W. S. 1201 Hartford Bldg., Chicago, Ill.	May 17, 1899
SHIPMAN, EUGENE H. Prest. Clear Springs Water Co., 624 North Main St., Bethlehem, Pa.	July 14, 1920
SHOEMAKER, G. E. Genl. Mgr., Water Works, Waterloo, Iowa,	June 5, 1911
SHOWELL, E. B., JR. Dupont-Rayon Co., Drawer B, Station B, Buffalo, N. Y.	Nov. 10, 1925
SHULL, J. W. Engineer, City Water Dept , 509 Market St., Wheeling, W. Va.	Nov. 24, 1924
SICKEL, H. B. ALLEN. Vice Pres., Layne-Ohio Co., 8 E. Broad Street, Columbus, Ohio	July 22, 1927
SIDDONS, JOS. S. V. Supt., Torresdale Filters, 1648 Dyre St., Frankford, Philadelphia, Pa.	Feb. 28, 1916
SIEBERT, CHRISTIAN L. District Engineer, Pennsylvania Dept. of Health, City Hall, Meadville, Pa.	Feb. 8, 1926
SIEDLE, ADOLPH G. Asst. Engr., Water Dept., 480 East 124th St., Cleveland, Ohio	June 13, 1921
SIEMS, V. BERNARD. Vice President & General Manager, North American Water Works Corp., 11 Broadway, New York, N. Y.	May 11, 1916
SIMMS, R. B. Supt. Water Works, Spartanburg, S. C.	May 24, 1922
SIMONS, GEORGE W., JR. San. Engr., 364 Avondale Ave., Jacksonville, Fla.	July 23, 1920
SIMPSON, A. G. Local Mgr., Chico Water Supply Co., 121 Broadway, Chico, Butte Co., Calif.	May 31, 1927
SIMPSON, J. H. 4770 Wallingford St., Oakland Station, Pittsburgh, Pa.	Sept. 11, 1924
SIMPSON, NATHAN A. Asst. Bact. Bureau of Water, 3818 Lancaster Ave., Philadelphia, Pa.	June 6, 1927
SINGLETON, M. T. Civil Engineer, P. O. Box 1878, Atlanta, Ga.	Sept. 18, 1925
SKIDMORE, JAMES E. Local Mgr., Hydro Electric Power Commission, Cobourg, Ont., Canada	Mar. 16, 1926
SKINKER, THOMAS JULIAN. Engr in Charge of Distribution, 312 City Hall, St. Louis, Mo.	July 31, 1924
SKINNER, ALFRED E. Western Mgr. Pitometer Co., 5311 Kenmore Ave., Chicago, Ill.	Mar. 14, 1921
SKINNER, HERVEY J. Pres., Skinner, Sherman & Esselen, Inc., 276 Stuart St., Boston, Mass.	Apr. 10, 1926
SKINNER, JOHN F. Deputy City Engr., 56 City Hall, Rochester, N. Y.	May 11, 1927
SLACK, MORRIS C. 53 Summit Ave., Albany, N. Y.	Jan. 26, 1926
*SLATER, E. O. Chemical Engr., 245 So. Los Angeles St., Los Angeles, Calif.	Apr. 11, 1922
SLAUGHTER, J. M. Supt., Water Works, Meridian, Miss.	May 28, 1924
SLEEPER, WM. H. 125–26—144th St., South Ozone Park, N. Y.	May 16, 1923
SLINGERLAND, MISS G. V. Pres., Suburban Water Co., Box 142, Slingerlands, N. Y.	Apr. 30, 1924

Smalley, James D. Supt. Water Dept., 1027 B St., Hayward, Ala. Co., Calif.	Aug. 29, 1923
Smalshaf, A. J. Columbus Water Works, Columbus, Ga.	Dec. 26, 1916
Smart, E. E. Commissioner of Water Sanitation, Mineral Wells, Texas	June 6, 1927
Smedberg, C. W. Water Dept., Greensboro, N. C.	Dec. 11, 1922
Smith, Albert B. 34 East Grand Ave., St. Louis, Mo.	Jan. 25, 1926
Smith, Arthur. East Ely, Nevada	May 20, 1925
Smith, Arthur H. 100 Beechwood Ave., Bound Brook, N. J.	May 8, 1918
Smith, Chester A. Cons. Engr., c/o Burns-McDonnell-Smith Engr. Co., 422 Western Pacific Bldg., Los Angeles, Cal.	Sept. 27, 1924
Smith, E. E. Manager, Water Department, Racine, Wis.	Apr. 23, 1927
Smith, E. H. New Jersey Water Co., 521–23 Federal St., Camden, N. J.	Apr. 20, 1924
Smith, Elroy G. Cons. Engr., 313 Herald Bldg., Augusta, Ga.	June 16, 1920
Smith, L. B. Mgr. Westmoreland Water Co., Greensburg, Pa.	July 26, 1915
Smith, Leon A. Supt. Water Works, City Hall, Madison, Wis.	May 17, 1916
Smith, M. C. Engineer in Charge Bureau Water & Electricity, Room 109, City Hall, Richmond, Va.	May 12, 1925
Smith, Milton Perry. Supt., Parks & Public Property, Sioux City, Iowa	Apr. 23, 1924
Smith, P. A. Treas., The A. P. Smith Mfg. Co., 66 Stanley Rd., South Orange, N. J.	May 31, 1927
Smith, R. J. Mgr., Sect.-Treas., Perth Hydro-Electric System, Perth, Ont., Canada	June 10, 1911
Smith, R. L. Supt., City Water Works, City Hall, Montrose, Colo.	Apr. 23, 1927
Smith, W. Austin, City Manager, Fort Pierce, Fla.	Dec. 22, 1926
Smith, W. Chester. City Engineer, City Hall, Oshawa, Ont., Canada	Feb. 8, 1926
Smith, W. Z. General Manager Water Works, 101 Rock Springs Road, Atlanta, Ga.	Apr. 27, 1910
Smithrim, E. R. Secty-Treas. Public Util. Comn., Box 55, Strathroy, Ont., Can.	Apr. 3, 1919
Snedeker, H. L. Local Manager, Willows District, California Water Service Co., Willows, Calif.	May 26, 1927
Snell, George H. 49 County St., Attleboro, Mass.	July 7, 1906
Snell, T. W. Genl. Supt. Coast Valleys G. & E. Co., Salinas, Calif.	Mar. 21, 1923
Snidow, Herman W. Asst. Engr., State Board of Health, Richmond, Va.	June 17, 1926
Snyder, Frederic Antes. 105 Carnegie Ave., East Orange, N. J.	Mar. 13, 1920
Snyder, James. Supt. Water Dept., 46 No. Main St., Perry, N. Y.	Nov. 10, 1925
Snyder, S. B. Supt. Wtr. Wks., 105 S. Madison St., Stoughton, Wis.	July 16, 1923
Soler, Pedro A. Rossell, Civil Engineer, Brasil 1777, Buenos Aires, R. A.	Aug. 5, 1927
Solomon, Gabriel R. Pres., Solomon, Norcross & Keis, P. O. Box 1917, Fort Lauderdale, Fla.	Nov. 18, 1925
Soost, C. W. Supt. Water Works, Mobile, Ala.	Oct. 27, 1922
Spalding, Geo. R. Asst. Supt., Filtration & Sanitation, Hackensack Water Co., New Milford, N. J.	June 17, 1926
Spaulding, Charles H. Supt. Water Purification, Dept. of Water Light & Power, Springfield, Ill.	July 29, 1924

Spear, Walter E. Municipal Bldg., Room 2224, New York, N. Y. .... Jan. 8, 1915
Speer, Carl, Jr. Sanitary Engineer, 7516 Colfax Ave., Chicago, Ill. .... Dec. 29, 1926
*Speller, Frank Newman. Metallurgical Engr., 1802 Frick Bldg., Pittsburgh, Pa. .... June 10, 1920
Spencer, C. A. Supt. Mountain Wtr. Supply Co., 208 Couler Bldg., Greensburg, Pa. .... Oct. 10, 1919
Spencer, Percy S., A.M.I.C.E. Resident Engineer, Newport Mon. Corpn. Water Works, Newport, Monmouthshire, England .... May 3, 1922
Sperry, Walter A. Director of Public Service, 630 Pleasant St., S. E., Grand Rapids, Mich. .... Dec. 5, 1914
Spire, Leonard S. Chf. Pitometer Operator, Bureau of Water, 50 Lake View Ave., Buffalo, N. Y. .... July 5, 1918
Spitznagel, Joseph. Supt. of Water & Light, Box 643, Gilbert, Minn. .... June 6, 1927
Squires, Anson W. Supt., Tampa Water Works Dept., P. O. Box 461, Tampa, Fla. .... Mar. 8, 1924
Stalbird, James A. Inspection Agua Potable, Augustinas 1336, Santiago, Chile .... Apr. 9, 1925
Stanfield, A. C., C. E. Pana, Ill. .... Dec. 24, 1914
Stanley, William E. c/o Pearse, Greeley & Hansen, 6 No. Michigan Ave., Rm. 1710, Chicago, Ill. .... Nov. 9, 1922
Stannard, Jay L. 212 City Hall Annex, Tacoma, Wash. .... Oct. 20, 1926
Starbird, H. R. 524 University Bldg., Syracuse, N. Y. .... June 13, 1921
Starke, William. Supt. of Municipal Water Dept., 416—3rd St., City Hall, San Bernardino, Calif. .... Nov. 15, 1926
Starr, Ronald H. B. A. Sc., Engr., Water, Light & Power Comm., Box 708, Orillia, Ont., Canada .... Jan. 16, 1920
Stava, William. Asst. Engr., Calif. R. R. Comm., Hyd. Divn., 2927 Regent St., Berkeley, Calif. .... May 17, 1927
Stearns, Harrington P. Long Island Water Corp., Far Rockaway, N. Y. .... Jan. 22, 1914
Stearns, Ralph H. 32 Elm Rock Rd., Bronxville, N. Y. .... May 31, 1924
Stein, I. Melville. 1317 Spruce Street, Philadelphia, Pa. .... May 26, 1925
Steinbruegge, R. L. Supt., Meter & Inspection Bureau, Water Div., 6452 McCune, St. Louis, Mo. .... June 6, 1927
Steinhauer, E. Local Manager, Redding District, California Water Service Co., Box 233, Redding, Calif. .... May 26, 1927
Stephen, Eng. Lt. Cmdr. Charles, R.N. Supt. Engr., Macdonald College, P. Q., Canada .... Apr. 21, 1916
Stephenson, Frank H. Asst. Supt. Water Supply, 5171 Webb Ave., Detroit, Mich. .... May 24, 1920
Stephenson, J. R. Superintendent City Water Works, Elkhart, Ind. .... Jan. 19, 1926
Stern, M. R. Gen. Mgr., Bartlesville Water Co., Wheeling Bank & Trust Bldg., Wheeling, W. Va. .... Feb. 17, 1927
Sterosky, Joseph. Supt. Water Dept., 909 Oak St., Port Huron, Mich. .... May 28, 1924
Stevens, Harold C. Consulting Engineer, 266 Fulton Ave., Hempstead, N. Y. .... May 9, 1914
Stevenson, Ralph A. Supt. Filtration Division, 3425-V. St., Sacramento, Calif. .... Sept. 14. 1927
Stevenson, W. L. Chf. Engr., Pa. Dpt. of Hlth., P. O. Box 622, Harrisburg, Pa. .... May 1, 1922
Stewart, C. E. Supt., Muncie Water Works Co., 316 S. Mulberry St., Muncie, Indiana .... Jan. 5, 1925
Stewart, E. B. Electrolysis Engineer, East Bay Water Company, P. O. Box 458, Oakland, Calif. .... May 28, 1926

Stewart, E. J. Engineer, Fire Protection, 701 Jackson St., Topeka, Kansas	Oct. 30, 1926
Stewart, Elon P. Engineer, Water Waste Survey, Bureau of Water, City Hall, Syracuse, N. Y.	May 6, 1926
Stewart, Fred J. City Engineer, City Hall Bldg., Hollywood, Fla.	Apr. 12, 1920
Stewart, Frederick G. Seneca Water Service Corp., Waterloo, N. Y.	May 28, 1924
Stewart, Spencer W. Prest. Ambursen Constr. Co. Inc., Grand Central Terminal Bldg., New York, N. Y.	Feb. 4, 1921
Stickney, Grosvenor W. City Engineer, 215 So. Washington St., Wheaton, Ill.	June 6, 1927
Stoldt, G. F. Hillview, Ill.	Dec. 16, 1922
Stompler, Otto F. Superintendent Langhorne Spring Water Co., Langhorne, Pa.	Jan. 6, 1926
Stone, E. W. Analyst, Pueblo Water Works, P. O. Box 818, Pueblo, Colo.	July 22, 1916
Stone, Ormond A. 1112 Hollingsworth Bldg., Los Angeles, Calif.	Jan. 2, 1924
Stone, R. D. Pres. & Mgr., 400 Chestnut St., Philadelphia, Pa.	Dec. 16, 1915
Storrie, William, C.E. Confederation Life Bldg., Room 625, Toronto, Ont.	Mar. 11, 1915
Storrs, John W., C.E. N. H. Pub. Serv. Comn., Concord, N. H.	Oct. 7, 1919
Story, Stephen Bond. Director Bur. Mun. Research, 25 Exchange St., Rochester, N. Y.	Mar. 30, 1920
*Stover, Frederick H. Crescent Hill Filters, Louisville, Ky.	June 3, 1912
Stradling, F. P. Supt. Kokomo Water Works Co., P. O. Box 369, Kokomo, Ind.	Dec. 29, 1924
Strang, John A., C.E. Wallace & Tiernan Co. Inc, 223 E. 9th St., Kansas City, Mo.	Feb. 8, 1923
Streander, Philip B. 7208 Hazel Ave., Bywood, Upper Darby, Pa.	Dec. 8, 1923
*Streeter, H. W. San. Engr., U. S. Pub. Hlth. Serv., Third & Kilgour Sts., Cincinnati, Ohio	Apr. 16, 1915
Streithof, Chas. R. R. #5, Box 169, Evansville, Ind.	May 23, 1923
Stringfellow, H. A. Manager, Pipe Division, The Biggs Boiler Works Co., Akron, Ohio	July 25, 1924
Strockbine, Walter. Chemist, Bureau of Water, Reading, Pa	June 6, 1927
Strohmeyer, Joseph S. Asst. Civil Engr. Water Dept., 5007 Wilson Ave., Baltimore, Md.	May 11, 1922
Strouse, Paul Ewing. City Engineer, Rocky Ford, Col.	Aug. 31, 1923
Struthers, D. L. City Manager, Gastonia, N. C.	Dec. 8, 1923
Sudheimer, George C. Comnr. Public Utilities, 25 East Fifth Street, St. Paul, Minn.	Mar. 13, 1925
Suggs, John H. Durham Water Works, Durham, N. C.	Apr. 4, 1924
Suitor, Roy B. Supt. Public Service, Walnut Ave. & 6th St., Niagara Falls, N. Y.	June 20, 1924
Sullivan, C. J. Supt. Water Works, 319 Second Ave. North, Chisholm, Minn.	June 23, 1913
Sullivan, E. C. Room 502, 45 Broadway, New York, N. Y.	Apr. 14, 1924
Sumner, R. S. Gen. Mgr., Denver Municipal Water Works, 1509 Cleveland Place, Denver, Colo.	Feb. 28, 1925
*Suter, Russell. Sr. Asst. Engr., Cons. Comn., Albany, N. Y.	Oct. 9, 1914
Suters, Frank. California Water Service Co., 401 San Joaquin Lt. & Power Bldg., Fresno, Calif.	July 11, 1927

SUTHERLAND, IAN M., M.C.E. Engng. Drftsmn. M. M. B.W., 110 Spencer St., Melbourne, Australia................ June 16, 1920
SUTHERLAND, OSCAR. Asst. Supt., Water Dept., Sioux City, Iowa.. June 6, 1927
SUTTLE, CLIFFORD B., C.E. Penarth Road & Lodges Lane, Cynwyd, Pa.................................... June 10, 1919
SUTTON, ROY E. Superintendent of Water Works, Route 7, Abilene, Kansas.................................... Feb. 17, 1927
SWAAB, S. M. Cons. Engr., City Hall, Room 210, Philadelphia, Pa.. Mar. 19, 1924
SWANSON, H. E. Supt., Water & Light Dept., Jacksonville, Ill.. June 6, 1927
SWANSON, MELVIN O. Supt. Water & Light Dept., City Bldg., Jamestown, N. Y............................. Aug. 9, 1922
SWARTZ, MARTIN. Supt. Water & Light Comn., Greenville, N. C.. Dec. 10, 1924
SWEARINGE, C. V. Chemist, City Water Company, Chattanooga, Tenn.. Jan. 2, 1924
SWEENEY, J. H. Chief Engr. Water Works, Wilmington, N. C. Dec. 8, 1923
SWEET, E. O., C.E. Birmingham Water Works Co., 1106½ Virginia Ave., Birmingham, Ala...................... May 19, 1916
*SWITZER, JOHN A. Cons. Engr., Prof. Hydraulic & Sanit. Eng., University of Tenn., Knoxville Tenn........... May 10, 1915
SYMONDS, GEORGE B. Filtration Works Superintendent, Mount Charlton, The Caves, North Coast Line, Queensland, Australia.................................... Aug. 16, 1927
SYMONDS, HENRY A. Cons. Hyd. Engr., 75 Crofton Road, Waban, Mass.. Feb. 26, 1921
SYMONS, JOHN Q. Foreman Operator, 2056 Main St., San Diego, Calif.. Oct. 20, 1926
SYMONS, M. M. Chief Engr., Interstate Water Co., 1009 West Fairfield St., Danville, Ill........................ Feb. 8, 1915

TABER, GEORGE A. 73 Cornhill, Boston, Mass.............. June 3, 1912
TAINTER, F. S., 84 Pine St., New York, N. Y................. Oct. 4, 1919
TAIT, ROBERT S. Superintendent of Water, 14 California St., Santa Cruz, Calif.................................... Oct. 27, 1925
TALBOT, ARTHUR N. Prof. Municipal & Sanitary Engr., University of Illinois, Urbana, Ill...................... Aug. 22, 1894
TALBOT, EARLE. Secty. Treasr. & Genl. Asst. Supt., Hackensack Water Co., Box F., Weehawken, N. J........... May 1, 1920
TALBOTT, FRANK. Supt. Sec. & Treas. Water Works, Danville, Va... June 7, 1904
TANCO, H. GOMEZ. Civil Engineer, Apartado 151, Bogota, Colombia.. Mar. 1, 1924
TANNER, I. B. Supt. Wtr. Svce. Dpt., Jos. E. Nelson & Sons, 3240 S. Michigan Ave., Chicago, Ill.............. Sept. 5, 1919
TARBETT, RALPH E. San. Engr. U. S. P. H. Serv., Box 1428, Norfolk, Va... July 5, 1921
TARR, CHARLES W. 4563 Oakwood Ave., Los Angeles, Calif... Apr. 26, 1926
TATOR, ARTHUR R. c/o Pure Asphalt Products Co., 136 Cator Avenue, Jersey City, N. J.................. Nov. 29, 1924
TAY, SAMUEL WRIGHT. San. Engr., Territorial Bd. of Hlth., Hawaii, 2413 Lower Manoa Road, Honolulu, T. H.... July 14, 1920
TAYLOR, ARTHUR. Cons. Engineer, 743 Petroleum Securities Bldg., 10th & Flower, Los Angeles, Calif......... July 31, 1924
*TAYLOR, GEO. R. San. Chmst., 115 Wyoming Ave., Scranton, Pa.. May 11, 1908
TAYLOR, STEPHEN H. Supt. Water Works, 312 Municipal Bldg., New Bedford, Mass.............................. June 3, 1919

TAYLOR, WARREN C. Assoc. Prof. of Civil Engr., Union College, Schenectady, N. Y.	Oct. 31, 1924
TENNY, M. K. Chemist, Des Moines Water Works, 10th & Locust Sts., Des Moines, Iowa	Feb. 17, 1927
THANE, H. S. Supt. Water Department, Missoula Public Service Co., Missoula, Mont.	Apr. 30, 1926
THERIAULT, EMERY J. Chemist, U. S. Public Health Service, 3rd & Kilgour Sts., Cincinnati, Ohio	Dec. 15, 1925
THIESSEN, FRANK C. Engineering Dept., R. R. Comm. Madison, Wis.	Oct. 7, 1924
THOMAS, A. H. R. Supt. Waterworks, Box 227, New Toronto, Ont.	Feb. 28, 1923
THOMAS, CHARLES F. 5915 Springfield Ave., Philadelphia, Pa.	Aug. 29, 1923
THOMAS, DAVID S. Inspecting Engineer, Board of Fire Underwriters of the Pacific, P. O. Box 1373, Butte, Mont.	Feb. 7, 1927
THOMAS, E. J. Cons. Engr., Box 613, Minot, N. Dak.	Dec. 11, 1922
THOMAS, EDGAR. Supt., Yreka Water Dept., Yreka, Calif.	June 6, 1927
THOMAS, M. L. Superintendent Water Works, Gillette, Wyoming	Mar. 27, 1926
THOMPSON, ALVIN B. Supt. Kennebec Water Dist., Waterville, Me.	June 26, 1919
*THOMPSON, DAVID G. Water Resources Branch, U. S. Geological Survey, Washington, D. C.	Sept. 24, 1924
*THOMPSON, RUDOLPH E. Asst. Chst. Filt. Plant, 596 Milverton Blvd., Toronto, Ont.	Mar. 16, 1922
THORNDIKE, STURGIS H. Consulting Engineer, Waterman Bldg., 44 School St., Boston, Mass.	Feb. 26, 1921
THORNE, F. H. Field Mgr. & Vice Pres., Chicago Chemical Co., 6216 W. 66th Place, Chicago, Ill.	June 6, 1927
THORPE, GEORGE E. Gen. Mgr., Thorpe Bros. Well Co., 224–226 Atlas Bldg., Des Moines, Iowa	May 24, 1927
*THUMA, R. A. Supt. Filter Plant, Water Department R. F. D. No. 4, Dayton's Bluff P. O., St. Paul, Minn.	Mar. 13, 1925
TIEDMAN, WALTER V. D. Asst., Sanitaria, Div. of Sanit., State Dept. of Health, Elsmere, N. Y.	Oct. 16, 1925
TILDEN, JAMES A. V. Pres. & Genl. Mgr. Hersey Mfg. Co., South Boston, Mass.	Apr. 19, 1889
TIPPINS. BEN. F. Gen. Supt., Water & Sewerage Plants, 517 Magnolia Ave., Daytona Beach, Fla.	Dec. 22, 1926
*TISDALE, ELLIS S. Director, San. Eng. Division, State Dept. of Health, Charleston, W. Va.	Aug. 26, 1916
TITSHAW, ERNEST P. Box 1814, Atlanta, Ga.	Mar. 16, 1927
TODD, WILLIAM. Supt. Elec. Light & Water Works, Austin, Minn.	June 18, 1901
TOLLES, FRANK C. Civil & Sanitary Engineer, 1149 Leader-News Bldg., Cleveland, Ohio	Aug. 1, 1923
*TOLSON, ALBERT. Supt. of Filters, 206 Rochelle Ave., Philadelphia, Pa	Jan. 29, 1916
TOMLINSON, O. N. Mgr. Hermosa Redonda Water Co., P. O. Box 235, Redonda Beach, Calif.	Dec. 10, 1924
TOMLINSON, SAM. 100 Robinson Road, Singapore, S. S.	July 14, 1887
TOMS, R. C. Mgr. Marion Water Co., Marion, Iowa	Apr. 4, 1924
TOTTEN, ROBERT L. Cons. Engr., 415 Brown Marx Bldg., Birmingham, Ala.	Mar. 26, 1923
TOWLE, ELTON L. Hydraulic & Mechanical Engineer, 341 Hamilton Ave., Glen Rock, N. J.	Apr. 5, 1922
TOWNLEY, DAVID H. Engr., Elizabethtown Water Co., 139 Murray St., Elizabeth, N. J.	May 26, 1916
TOYNE, J. W. Engineer, South Bend, Ind.	July 10, 1906

Trace, V. E. Supt. Water Works Dept., City Hall, Santa Barbara, Calif. .... July 23, 1920
Trauger, George W. Supt. Lindsay Strathmore, Irrigation District, Box 57, Lindsay, Calif. .... Nov. 18, 1925
Travis, F. M. Pres., The Torrington Water Co., P. O. Box 76, Torrington, Conn. .... July 20, 1917
*Trax, E. C. Chemist, Filtration Plant, McKeesport, Pa. .... June 9, 1911
Tremblay, J. A., C.E. Engr., Water & Sewerage Dept., 98 Bougainville Ave., Quebec, Canada .... May 28, 1924
Tribus, Louis Lincoln, C.E. 15 Park Row, New York, N. Y. May 12, 1906
Trimble, Earle J. Supervising Engr., Water Dept., 85 Otsego St., Ilion, N. Y. .... May 15, 1924
Trogdon, J. S., C.E. Box 11, Guilford College, N. C. .... Dec. 11, 1922
True, Albert O. Sanitary Engr., Proximity Mfg. Co., Denim Branch, Greensboro, N. C. .... Aug. 28, 1922
Truman, Chester A. Supt., Northfield Land & Water Co., 3011 N. Tejon St., Colorado Springs, Colo. .... Dec. 27, 1926
Trumbore, Frank J. Master Mechanic, 1151 N. Main St., Pleasantville, N. J. .... Apr. 7, 1922
Turner, J. W. Superintendent, Waterworks, Edmonton, Alberta, Canada .... June 6, 1922
Turner, Joseph J. Asst. Sect., Boise Water Co., Box 718, Boise, Idaho .... Jan. 14, 1925
Tuttle, Arthur S. Chf. Engr., Bd. of Estimate & Apportionment, Municipal Building, New York, N. Y.. July 10, 1916
Tyler, D. M. Supt. Elkins Water Works, 153 River St., Elkins, W. Va. .... Feb. 20, 1924
Tyler, O. Z. Superintendent Water Dept., City Engineer Bldg., Jacksonville, Fla. .... June 17, 1926

Ulrich, Bernard L. Supt., Water Works, Manhattan, Kansas .... Feb. 20, 1922

Vail, Charles D. Mgr. Improvements & Parks, City Hall, Denver, Col. .... Jan 8, 1921*
Vail, R. M. Asst. Supt., Spring Brook Water Supply Co., 30 N. Franklin St., Wilkes Barre, Pa. .... Nov. 27, 1923
Valentino, John G. Supt. Water Dept., Savannah, Ga. ... Apr. 30, 1923
*VanArnum, William I. Supt. Filtration, 113 Halls Heights Ave., Youngstown, O. .... Feb. 7, 1922
Van Arsdale, George A. Water Superintendent, Hugo, Colorado .... Apr. 10, 1926
Van Benschoten, Jay. Mechanic & Water Works Engr., 32 Front St., W., Toronto, Ont., Canada .... June 10, 1923
VanBrunt, W. D. Pres. Water Works Co., Southampton, N. Y. .... Aug. 23, 1920
Van Cleave, Sam M. Supt., City Water Works, City Hall, Marion, Ind. .... Apr. 10, 1926
Van den Berg, C., Jr. Vice Pres., Alabama Water Co., 1019 American Trust Bldg., Birmingham, Ala. .... Apr. 23, 1927
Van Deusen, E. T. Supt., Water Works, 21 Pearl St., Malone, N. Y. .... Feb. 14, 1925
Van Doren, Wm. Theo. Water Survey Engineer, Bryant St. Pumping Sta., Washington, D. C. .... May 18, 1926
Van Gilder, L. Engr. & Supt. Water Dept., City Hall, Atlantic City, N. J. .... July 10, 1906
Van Gorder, J. R. Eastern Sales Manager, Neptune Meter Company, 50 E. 42nd St., New York, N. Y. .... Mar. 20, 1922
VanKeuren, C. A. Chief Engr., Wat. Dept., City Hall, Jersey City, N. J. .... May 23, 1923

*VAN LOAN, SETH M. Deputy Chief, Bureau of Water, 709 City Hall, Philadelphia, Pa.	May 12, 1914
VAN TRUMP, S. N. Chf. Engr. & Supt. Water Wks., Wilmington, Del.	Feb. 7, 1916
VAUGHN, W. H. Water Superintendent, Fort Smith, Ark.	June 6, 1927
*VEATCH, N. T., JR. Cons. Engr., 701–5 Mutual Building, Kansas City, Mo.	Dec. 16, 1915
VERMETTE, NARCISSE J. A. City Manager, Shawinigan Falls, Can.	Feb. 7, 1927
VERMEULE, CORNELIUS C., C.E. 38 Park Row, New York, N. Y.	June 8, 1909
VERSULIUS, JAS. J. Construction Engineer, 403 City Hall, Chicago, Ill.	June 5, 1926
VERTEFEUILLE, JOSEPH A Municipal Bldg., Brooklyn, N. Y.	May 16, 1916
VEST, W. E. Supt. Water Works, Charlotte, N. C.	May 3, 1911
VICINI, HOYT C. Supt., Venice Consumers Water Co., 440—17th St., Santa Monica, Calif.	July 12, 1926
VOGELBACK, WILLIAM E. Southern States Power Co., 100 W. Monroe St., Chicago, Ill.	Feb. 8, 1926
VOJCSIK, LIPOT, C.E. Budapest IX, Ulloi ut 69, Hungary.	July 19, 1926
VOLK, KENNETH Q. 543 Petroleum Securities Bldg., 10th & Flower Sts., Los Angeles, Calif.	Oct. 18, 1926
VOLLMAR, OTTO. Director, Dresden Water Works, Brockhausstrasse 3, Dresden, N. 8, Germ.	Mar. 13, 1925
VON GREYERZ, WALO, C.E. Capt. Royal Swedish Corps Engrs., Humlegardsgatan 29, Stockholm, Sweden.	July 23, 1920
*VOSBURY, W. DEWITT. Hydraulic & Sanitary Engr., 509 Cooper St., Camden, N. J.	Jan. 19, 1924
*WACHTER, LEONARD M. Chemist, Dept. of Health, 192 Partridge St., Albany, N. Y.	Mar. 16, 1922
WAGGONER, GEORGE. Supt., Carlisle Gas & Water Co., Carlisle, Pa.	May 12, 1925
WAGNER, C. F. Engr., Oregon Insur. Rating Bur., P. O. Box 745, Portland, Oregon	Nov. 30, 1925
WAGNER, EDWIN B. Supt. Water Works, Downingtown, Pa.	Apr. 22, 1921
*WAGNER, HENRY F. Chief Chemist, Bureau of Water, Filtration Division, Buffalo, N Y	May 12, 1914
WAGNER, RICHARD F. Supt. & Engr. Dept. of Water, Lynchburg, Va.	Nov. 3, 1919
WAHL, BENJAMIN. Chf. Chst. Detroit Sulph. P. & P. Co., Detroit, Mich.	June 8, 1923
*WALDEN, A. E. Supt. & Chief Engineer, 26 Hamilton Ave., Raspeburg P. O., Baltimore, Md.	May 12, 1908
WALDROP, GEORGE G. Secretary, Water Works, Room 3, City Hall, Fort Wayne, Ind.	Apr. 10, 1926
WALKER, CARL C. Civil Engineer, 511–12 Hartman Bldg., Columbus, Ohio.	Jan. 26, 1924
*WALKER, ELTON D. Prof. of Hydrau. & San. Engrg., Pennsylvania State College, State College, Pa.	July 18, 1906
*WALKER, ISAAC S. Genl. Mgr. New Chester Wtr. Co., 594 Drexel Bldg., Philadelphia, Pa.	Mar. 25, 1919
WALKER, J. E. 2 Dalhousie Square, Post Office Box 680, Calcutta, India.	Nov. 12, 1926
WALKER, LEWIS DEWAR. Water Works Engineer, Canadian Fire Underwriters Asso., Metropolitan Bldg., Toronto, Ont., Canada.	Feb. 10, 1921
WALL, EDWARD E. 5361 Pershing Ave., St. Louis, Mo.	June 7, 1904
WALL, W. A. Construction Engr., Water & Sewer Department, King & Alakea Sts., Honolulu, T. H.	Apr. 10, 1922

*Wallace, William M. Filter Supt. & Chief Chemist, Filtration Plant, Water Wks. Park, Detroit, Mich. .... Apr. 5, 1922
Walsh, John H. 265 Burnside Ave., East Hartford, Conn... May 28, 1924
Ward, Charles Maxwell. Cons. Engineer, E. Laurie Co., 115 Stanley St., Montreal, P. Q., Canada............... June 10, 1920
Ward, Joe E., C.E. Montgomery & Ward, Cons. Civil Engrs. 545 Harvey-Snider Bldg., Wichita Falls, Texas......... June 17, 1926
*Ward, Thomas H. P. O. Box 613, Fort Smith, Ark......... May 28, 1924
Warder, Charles. Superintendent Water Works, Niagara Falls, Ont.. Jan. 8, 1916
Wardle, Andrew N. 15 West Seventh St., Tulsa, Okla..... Sept. 18, 1916
*Waring, F. Holman. Chief Engineer, State Dept. of Health, Columbus, Ohio............................ Feb. 23, 1915
Warnecke, M. H. Supt. Water Works, 216 So. 10th Ave., Maywood, Ill.. Mar. 27, 1926
Warner, H. L. Messrs. Crane-O'Fallon Co., 1631—15th St., P. O. Box 239, Denver, Colo.......................... Jan. 25, 1927
Warren, C. A. Const. Engr., City Water Department, 1822 E. Lafayette Ave., Baltimore, Md.................... May 24, 1922
Warren, Herbert C. Genl. Mgr., Glendora Cons. Mutual Irr. Co., 234 N. Michigan Ave., Glendora, Calif........ Mar. 16, 1927
Warren, W. D. P. Cons. Engr., Milliken Bldg., Decatur, Ill. Mar. 20, 1920
Warrick, Louis F. Asst. Sanitary Engineer, State Board of Health, Madison, Wisc.............................. Apr. 6, 1920
*Waterman, Earle Lytton. Professor San. Engr., 104 Eng. Hall, University Ia., Iowa City, Iowa............... Dec. 11, 1922
Watkins, Thomas. Mechanical Engr., Johnstown, Pa...... May 18, 1892
Watson, William. Supt., Water & Light Dept., City Hall, Owensboro, Ky... Mar. 8, 1924
Watt, D. M. Mgr. American Water Works & Elec. Co., 50 Broad St., New York, N. Y........................... Apr. 23, 1924
Watt, H. E. Supt. Huntington Water Corpn., Huntington, W. Va.. Aug. 13, 1924
Watts, H. T., C.E. Supt. Water Supply Co., Box 107, Vincennes, Ind.. July 7, 1920
Weaver, F. F. Chemist, General Chemical Co., P. O. Box 147, Long Island City, N. Y............................. Dec. 13, 1924
Weaver, S. M. Superintendent Water Works, Monroe, Mich... Jan. 19, 1925
Webb, S. W. Dist. Mgr. Consumers Power Co., Cadillac, Mich.. Jan. 8, 1921
Webster, Wade L. Director Public Works, Kingsport, Tenn. Dec. 20, 1926
Wechter, W. E. Mechanical Engineer, 217 W. 11th St., Jacksonville, Fla.. Apr. 23, 1927
Weed, Ellsworth S. Civil Engineer, 232 Maclay St., Harrisburg, Pa.. July 12, 1926
Weed, Frederick H. Gannett, Seelye & Fleming, 600–602 North 2nd St., Harrisburg, Pa........................ Nov. 10, 1925
*Weidlein, E. R. Sc.D., Mellon Ins. of Ind. Research, Thackeray & O'Hara Sts., Pittsburgh, Pa.............. June 26, 1924
Weir, W. H. Asst. Engr., Dept. of Engrng., State Board of Health, Raleigh, N. C.............................. Dec. 29, 1924
Weir, W. V. 6600 Delmar Blvd., University City, Mo....... July 14, 1924
Welch, J. N. Superintendent of Water Works, Bryson City, N. C... Aug. 28, 1926
Welfelt, W. J. City Manager & Water Supt., Winfield, Kansas.. June 6, 1927
Wells, George M. Consulting Engineer, 61 Broadway, New York, N. Y... May 5, 1913

WELLS, MARVIN. Superintendent Water Works, 1333 Washington St., Des Plaines, Ill. .... June 17, 1926
WELSFORD, HENRY REED. Supt., Belmont Filter Plant, Bur. of Water, Belmont Ave., & Ford Road, Philadelphia, Pa. .... Apr. 23, 1927
WENTWORTH, FRANKLIN H. Sect., National Fire Protection Assoc., 40 Central St., Boston, Mass. .... May 28, 1924
WENTWORTH, JOHN P. Metcalf & Eddy, 1300 Statler Bldg., Boston, Mass. .... July 10, 1926
WERTZ, C. F. 1843 W. Erie Ave., Philadelphia, Penna. .... Mar. 25, 1924
*WESLEY, J. B. Chemist, Mo. Pacific R. R., 632 Railway Exc. Bldg., Kansas City, Mo. .... Apr. 24, 1922
WEST, CHAS. C. Gen. Mgr., Sayre Water Co., Sayre, Pa. Dec. 21, 1922
WEST, GEO. F. President, Biddeford & Saco Water Co., Portland, Me. .... July 24, 1911
WEST, GEORGE M. Supt., Post Office Bldg., 182 S. 2nd St., Lehighton, Pa. .... Mar. 17, 1916
WEST, VERNON F. Rensselaer Water Co., Box 868, Portland, Maine .... June 19, 1914
*WESTON, ROBERT SPURR. Consulting Sanitary Engr., 14 Beacon St., Boston, Mass. .... June 15, 1898
WETTER, CLARENCE H. Supt. Water Works, Tiffin, Ohio .... July 15, 1915
WHEDBEE, EDGAR. District Sanitary Engineer, Texas State Board of Health, 601 W. 10th St., Bonham, Texas ..... June 17, 1926
*WHEELER, ROBERT C. Barker & Wheeler, 36 State St., Albany, N. Y. .... Oct. 23, 1914
WHEELER, WILLIAM. Consulting Civil Engr., 14 Beacon St., Boston, Mass. .... July 10, 1906
WHIPPLE, MELVILLE C. Asst. Prof. of Sanitary Chemistry, 112 Pierce Hall, Cambridge, Mass. .... May 13, 1922
WHITACRE, R. D. Supt. of Water Dept., City Hall, Tucson, Ariz. .... Sept. 28, 1926
WHITE, CHARLES H. Supt. Water Dept., Box 744, Asbury Park, N. J. .... May 28, 1924
WHITE, GEORGE W. Civil Engr., Harwood Beebe Co., 12 Glenn Bldg., Spartanburg, S. C. .... Dec. 29, 1924
WHITE, GILBERT C., C.E. Durham, N. C. .... May 12, 1908
WHITE, GUY H. Superintendent Water Plant, 2217 Gadsden St., Columbia, S. C. .... Nov. 24, 1925
WHITE, HENRY M. Supt., Water Works, Oneida, N. Y. .... May 24, 1922
WHITE, I. A. Superintendent Water Works, Bessemer City, N. C. .... Dec. 8, 1923
WHITENER, J. SUMMIE. 1202 Cowper Drive, Raleigh, N. C. . Dec. 13, 1924
WHITLEY, L. G. 408 S. Tarboro St., Wilson, N. C. .... May 28, 1924
*WHITMAN, EZRA B. Civil & Sanitary Engr., 1828 Munsey Bldg., Baltimore, Md. .... Apr. 19, 1910
WHITMIRE, C. D. 5725 Grand Ave., Kansas City, Mo .... Apr. 13, 1926
WHITSIT, LAWRENCE C. City Engineer, 110 California Ave., Highland Park, Mich. .... May 7, 1917
*WHITTAKER, H. A. Director, Division of Sanitation, State Board of Health, Minneapolis, Minn. .... June 24, 1913
WIEDEMAN, H. F. Prin. Asst., with Paul H. Norcross, Engr., 76 Williams Mill Road, Atlanta, Ga. .... Mar. 27, 1925
WIEGHARDT, GEO. F., C.E. Tech. Advisor & Bus. Mgr. of Schools, 812 East 33rd Street, Baltimore, Md. .... Mar. 25, 1924
WIETERS, A. H. Chf. Engr., Div. of Sanitary Eng. & Housing, State Dept. of Health, Des Moines, Iowa .... Nov. 14, 1921
WIGGIN, THOMAS H. Cons. Engr., 415 Lexington Avenue, New York, N. Y. .... May 24, 1922

WIGHT, H. C. Industrial Engr., 806-7 Dayton Savings & Trust Bldg., Dayton, Ohio.......... May 12, 1915
WIGLEY, CHESTER G., C.E. Room 230, Guarantee Trust Bldg., Atlantic City, N. J.......... Apr. 27, 1910
WILBUR, C. C. R. I. Box 15, Fridley, Minn.......... Feb. 20, 1924
WILCOX, FRANK L. Cons. Engr., Chemical Building, St. Louis, Mo.......... Apr. 28, 1914
WILCOX, WILLIAM F., M.E. 1205 Fourth National Bank Bldg., Atlanta, Ga.......... Sept. 5, 1893
WILHELM, E. G. Secty-Treasr., Williamsport Water Co., Williamsport, Pa.......... Feb. 15, 1917
WILHELM, GEORGE. Chief Engr. East Bay Water Co., Oakland, Cal.......... Mar. 25, 1913
WILL, CHARLES K. Supt. Water Works, 118 S. Queen St., Lancaster, Pa.......... Feb. 19, 1919
WILLARD, ERNEST C. 720 Corbett Building, Portland, Oregon.......... Oct. 10, 1914
*WILLCOMB, GEORGE E. San. Engr., 12 So. Lyons Ave., Albany, N. Y.......... Apr. 7, 1922
WILLETT, J. F. Supt. City Water Dept., Billings, Mont.......... Apr. 28, 1915
WILLETT, WILLIAM N. Genl. Mgr. Murphysboro Wtr. Wks., Elect. and Gas. Light Co., Aurora, Ill.......... Sept. 21, 1918
WILLIAMS, D. M. Assistant Engr., c/o Wm. M. Piatt, Durham, N. C.......... May 18, 1923
WILLIAMS, GARDNER S. Cons. Engr., Cornwell Bldg., Ann Arbor, Mich.......... July 10, 1906
WILLIAMS, HOWARD L. Supt. Water Works, Ludington, Mich. Aug. 24, 1894
WILLIAMS, O. E. Pres., Marion Water Co. & Tiffin Water Wks., 42 S. Russell St., P. O. Box 3378, Boston, Mass.. June 6, 1927
WILLIAMS, R. B., JR. General Manager, Syracuse Suburban Water Co., 148 No. Warren Street, Syracuse, N. Y..... Mar. 19, 1926
WILLIAMSON, D. CHARLES. 5 Orchard St., Bernardsville, N. J. Jan. 16, 1923
WILLIAMSON, JAMES E. Cons. Engr., 39 Cortland St., New York, N. Y.......... Jan. 20, 1921
WILLIAMSON, LEE H. Williamson, Carrol & Saunders, Natl. Bank Bldg., Charlottesville, Va.......... May 5, 1922
WILLS, W. COMPTON. Assistant Engineer of Distribution, Water Dept., 16th and French Sts., Wilmington, Dela. July 10, 1926
WILLSON, WILLIAM JAY. Supt. Water Works, Greenwich, Conn.......... June 7, 1916
WILSON, EDGAR KENNARD. 54 Carolin Road, Upper Montclair, N. J.......... Mar. 6, 1926
WILSON, EVERITT W. R. W. Hebard & Co., Inc., Medellin, Colombia.......... Dec. 20, 1925
WILSON, I. E. Wtr. Commissioner, City Hall, Faribault, Minn.......... Sept. 21, 1922
WILSON, JESSE H., C.E. City Engineer, Idaho Falls, Ida...... July 31, 1924
WILSON, JOHN. City Hall, Duluth, Minn.......... Dec. 22, 1909
WILSON, JOHN J. District Engineer, Natl. Tube Co., 1020 First Natl. Bank Bldg., Denver, Colo.......... Mar. 10, 1926
WILSON, NORMAN MCLEOD RAMSAY. Chf. Engr., Water Comnrs., Brantford, Ont., Canada.......... Dec. 26, 1919
WILSON, PERCY S. Supt., New Rochelle Water Co., 514 Main St., New Rochelle, N. Y.......... July 16, 1962
WINKLE, CHARLES W. Supt., Maintenance & Transportation, Indianapolis Water Co., 620 N. Market St., Indianapolis, Ind.......... Dec. 29, 1924
*WINSLOW, C.-E. A. Yale Medical School, New Haven, Conn.. Jan. 30, 1915
WINSLOW, W. H. Vice Prest. Superior W., Lt. and Pr. Co., Superior, Wis.......... June 8, 1909

WINSOR, FRANK E. Chf. Engr., Metropolitan Dist. Water Supply Commission, 24 School St., Boston, Mass....... Jan. 26, 1924
WINTERMUTE, FERD C., C.E. 404 Second National Bank Bldg., Wilkes Barre, Pa.................................... Dec. 16, 1922
WINTGENS, PETER J. Supt. Wtr. Wks., 1201 Fifth Ave., Ford City, Pa.................................... May 23, 1923
WOLBERT, H. E. Supt. Bd. of Water Supply, Mount Vernon, N. Y.................................... May 26, 1916
WOLF, H. CARL. Chief Engr. Public Serv. Comm., 1724 Munsey Bldg., Baltimore, Md.................... Feb. 27, 1924
WOLFE, ED. C. Supt. Water & Light, 211 S. State St., Greenfield, Ind.................................... Dec. 29, 1924
*WOLFE, EDWARD E. Chemist, Water Dept., Hannibal, Mo.... Apr. 24, 1922
WOLFE, THOMAS F. Resrch. Engr., Cast Iron Pipe Pub. Bur. 566 Peoples Gas Bldg., Chicago, Ill................. Mar. 16, 1922
*WOLMAN, ABEL. San. Engr., 16 West Saratoga St., Baltimore, Md.................................... Mar. 11, 1918
WOLTMAN, J. J., C.E. 225 Unity Bldg., Bloomington, Ill.... May 20, 1923
WOOD, C. LELAND. Supt. of Municipal Commission, Herkimer, N. Y.................................... July 19, 1927
WOOD, LEONARD P. Asst. Engr., Board of Water Sup. of N. Y. C., 2217 Municipal Bldg., New York, N. Y........... Mar. 5, 1924
WOODS, HARLAND CLARK. 442 Grove St., E. Lansing, Mich... Aug. 14, 1919
WOODWARD, FRANK L. Jr. San. Engr., Minnesota Dept. of Health, Minneapolis, Minn.......................... May 11, 1927
WOOLLEY, JAMES. Meter Laboratory Chf., 135 4th St., Newark, N. J.................................... June 21, 1920
WOOLNOUGH, FREDERICK, J. 1364 Albany Ave., Brooklyn, N. Y.................................... Apr. 14, 1924
WORRELL, M. L. Engr. and Mgr. City Wtr. Wks., Vicksburg, Miss.................................... June 24, 1903
WORTH, A. M. P. O. Box 282, Chapel Hill, N. C........... Apr. 23, 1924
WRAY, WALTER. Box 487, Tustin, Calif.................... Nov. 11, 1926
WRIGHT, C. F. Supt., Light & Water Dept., Lake Worth, Fla.................................... Jan. 25, 1927
WRIGHT, C. W. Pres., Badger Meter Mfg. Co., 841—30th St., Milwaukee, Wis.................................... Mar. 19, 1927
WRIGHT, E. L. Superintendent, Municipal Water Works, Orland, Glenn Co., Calif.......................... June 20, 1922
WRIGHT, HOWELL. Director of Public Utilities, 204 City Hall, Cleveland, Ohio.................................... June 17, 1926
WRIGHT, JAS. Supt., Dundas Water Works, Dundas, Ont., Canada.................................... Apr. 29, 1924
*WRIGHT, JOHN G. Engr. and Filter Operator, 312 Lincoln St., Sayre, Pa.................................... June 30, 1921
WRIGHT, LEROY H. Superintendent of Water Works, 516 Colton Ave., Newark, N. Y.......................... Apr. 12, 1927
WRIGHT, STANLEY HUBERT. Consulting & Hydraulic Engr., Box 24, Hendersonville, N. C....................... July 13, 1923
WUESTE, R. G. City Hall, San Diego, Calif............... May 12, 1925
WYANT, CARL. Resident Engr., Montecito County Water Dist., 29 San Ysidro Rd., Santa Barbara, Calif......... Mar. 5, 1924
WYCKOFF, CHARLES R. 1239 N. Y. Post Rd., Scarsdale, N. Y.................................... Apr. 2, 1918
WYCKOFF, NORMAN R. Dept. of Water Supply, Detroit, Mich. Sept. 11, 1923
WYNNE-ROBERTS, R. O. Suite 902, Metropolitan Bldg., 44 Victoria St., Toronto 2, Ont. Canada.................. June 24, 1903

YAXLEY, R. GORDON. Supt. to Water Commissioners, Waterford, N. Y.................................... Oct. 13, 1925

Yegen, William. Supt. of Filtration Plant, 808 Main Avenue Bismarck, N. D.	June 6, 1927
Yoder, Joseph D. Water Purification Engineer, Cochrane Corporation, 17th St. and Allegheny Ave., Philadelphia, Pa.	Feb. 8, 1926
Younce, W. L. 121 S. 7th St., Newcastle, Ind.	July 1, 1924
Young, T. L. Mgr. South Side Water Works Co., Chester, W. Va.	June 13, 1921
Young, Wm. R. Registrar Water Works, City Hall, Minneapolis, Minn.	June 8, 1904
Zell, T. H. Superintendent Water Dept., Xenia, Ohio	May 23, 1923
Zilken, Andrew J. 301 East 2nd Street, Austin, Texas	Apr. 27, 1925
Zimmerlin, Harry F. Supt. of Water, Lyons, N. Y.	June 3, 1921

CORPORATE MEMBERS

Adirondack Water Works. Lowville, N. Y.	Jan. 12, 1923
Agua Pura Co. 701 Douglas Ave., East Las Vegas, N. M.	May 24, 1909
Alabama Power Co. Howard Duryea, Asst. to General Manager, Birmingham, Ala.	Feb. 23, 1926
Alexandria Water Co. Alexandria, Va.	Apr. 3, 1909
Allentown Water Department. City Hall, Allentown, Pa.	May 31, 1922
American Water Works and Electric Co., Inc. Mr. H. Hobart Porter, Prest., 50 Broad St., New York, N. Y.	June 24, 1915
Anaconda Copper Mining Co. Water Works Dept., Anaconda, Mont.	June 4, 1910
Ann Arbor Water Works Commission. City Hall, Ann Arbor, Mich.	Apr. 14, 1919
Antioch, Calif. John F. Linwood, City Hall, Antioch, Calif.	Sept. 30, 1926
Arkansas Power & Light Co. Pine Bluff, Arkansas	May 18, 1909
Arkansas Utilities Company. 311 Porter Street, Helena, Arkansas	May 12, 1925
Ashland Water Commission. E. C. Means, Chairman, Ashland, Ky.	Apr. 10, 1925
Ashtabula Water Supply Co., A. T. Faulkner, Manager, Ashtabula, Ohio	Mar. 5, 1924
Auburn Water Department. Auburn, New York	Mar. 8, 1911
Baton Rouge Water Works Co. Baton Rouge, La.	Apr. 13, 1914
Bay City Water Works Dept. City Hall, Bay City, Mich.	Aug. 24, 1925
Benicia Water Co. J. A. Wilcox, Chf. Engr., 603 Wells Fargo Bldg., San Francisco, Cal.	May 29 1920
Bethlehem, Penna., City of. 37 E. Broad Street, Bethlehem, Pa.	Apr. 27, 1925
Beverly Hills Water Department. C. L. Kimball, Field Supt., City Hall, Beverly Hills, Cal.	Sept. 21, 1926
Birmingham Water Co. 22 Elizabeth St., Derby, Conn.	May 26, 1909
Bisbee-Naco Water Company, P. O. Box 1159, Bisbee, Ariz.	Sept. 8, 1924
Boulder Water Department. E. W. Devalon, Director of Public Serv., Boulder, Colo.	Jan. 27, 1927
Brampton Water Commission. Brampton, Ont., Canada	Feb. 28, 1923
Brantford Water Commissioners. Brantford, Ont., Canada	May 15, 1914
Buffalo, Bureau of Water, 2 Municipal Bldg., Buffalo, N. Y.	June 9, 1921
Burbank, Calif. Public Service Department, J. H. McCambridge, Genl. Supt., 124 N. Olive, Burbank, Calif.	June 6, 1927
Canon City, Colo. Alfred W. Stedman, Water Supt. & Plumbing Inspector, City Hall, Canon City, Colo.	Apr. 13, 1926
Canton Water Works. City Hall, Canton, Ill.	Oct. 14, 1914
Central Illinois Public Serv. Co. D. W. Johnson, Water Engr., Public Service Bldg., Springfield, Ill.	Mar. 22, 1927
Charleston Commissioners of Public Works, 14 George St., Charleston, S. C.	May 23, 1912
Chatham, Ont. Board of Water Commissioners, C. H. R. Fuller, City Mgr., Chatham, Ont., Canada	Feb. 16, 1924
Citizens Water Co. 62 E. Wheeling St., Washington, Pa.	Jan. 6, 1927
Citizens Water Supply Co. Elmhurst, Long Island, N. Y.	Jan. 30, 1911

Columbus, Delaware & Marion Elec. Co. L. C. Stang, 198 S. Main St., Marion, Ohio.......... Apr. 10, 1926
Community Water Service Co. Reeves J. Newsom, Vice Pres., 46 Cedar St., New York, N. Y.......... Jan. 6, 1927
Connecticut State Dept. of Health. 8 Washington Street, Hartford, Conn.......... Sept. 6, 1924
Conservative Water Co. W. W. Pedder, Pres., 8619 Fir St., Los Angeles, Cal.......... Nov. 3, 1919
Corning Water Works. Corning, N. Y.......... Apr. 9, 1913
Creston, Iowa. Taxpayers Municipal Water Works, Creston, Iowa.......... May 10, 1919

Dallas City Waterworks. S. E. Moss, Commissioner, Dallas, Texas.......... June 6, 1927
Dayton Power & Light Co. 130 North South St., Att'n H. I. Fox, Supt., Wilmington, Ohio.......... Feb. 16, 1924
Delavan Water Commission. O. W. Blanchard, Supt., Delavan, Wis.......... June 10, 1923
Deming Water Dept. Municipal Plant, Deming, N. Mex.. May 21, 1919
Dover Water Commissioners. Jos. V. Baker, Clerk, Morris Co., Dover, N. J.......... May 22, 1918
Dubuque City Water Works. J. W. McEvoy, Supt., Dubuque, Ia.......... May 13, 1919
Dunbar Water Co. Dunbar, W. Va.......... Mar. 19, 1924

Eagles Mere Water Co. 253 West Fourth St., Williamsport, Pa.......... Apr. 10, 1914
East Bay Water Co. S. M. Marks, Secy., Oakland, Calif... June 24, 1915
East Orange Board of Water Commissioners. Paul C. Carey, President, East Orange, N. J.......... Aug. 14, 1909
Ellwood Water Co. 835 Lawrence Ave., Ellwood City, Pa.......... Jan. 19, 1925
Elmira Water Board. Elmira, N. Y.......... Mar. 11, 1915
Emporia Water Department. City Bldg., Emporia, Kans.. Jan. 16, 1924
Emporium Water Co. Emporium, Pa.......... Mar. 6, 1926
Erie Commissioners Water Works. 701 French St., Erie, Pa.......... May 31, 1911
Evansville Water Works. Evansville, Ind.......... May 7, 1906

Federal Light & Traction Co. 52 William St., New York, N. Y.......... Mar. 8, 1920
Flint, Mich. Board of Water Commissioners, 509 Harrison St., Flint, Mich.......... Nov. 18, 1925
Fond du Lac, Mich. City Water Department, L. P. Peeke, Superintendent, Fond Du Lac, Wisc.......... May 22, 1919
Fort Collins, Colorado.......... Mar. 16, 1926

Gananoque Water Works Commission. H. D. Rogers, Supt. Gananoque, Ont., Canada.......... Mar. 16, 1927
General Inspection Bureau. Lock Drawer 1746, Minneapolis, Minn.......... Feb. 9, 1924
Glendale, Calif. Public Service Department, Peter Diederich, Supt., 575 Broadway, Glendale, Calif.......... Dec. 24, 1914
Glen Ridge Water Department. A. F. Eschenfelder, Glen Ridge, N. J.......... Oct. 27, 1922
Glens Falls Board of Water Commissioners. Glens Falls, N. Y.......... Oct. 24, 1918
G. V. Grace & Co. G. Vincent Grace, 34 Pine St., New York, N. Y.......... Oct. 22, 1926

GRAND JUNCTION, COLO. John J. Burroughs, Supt. Water Dept., Grand Junction, Colo	Mar. 30, 1926
GRAND RAPIDS DEPARTMENT OF PUBLIC SERVICE. Grand Rapids, Mich.	**Feb. 14, 1913**
GREAT FALLS WATER DEPT. Great Falls, Montana	Jan. 31, 1925
GREELEY, COLO. M. Seaman, Water Supt., Greeley, Colo.	Apr. 30, 1926
GREEN BAY WATER DEPT. James Church, Supt., Green Bay, Wis.	**Nov. 3, 1914**
GRIFFIN LIGHT, WATER & SEWERAGE DEPT. Griffin, Georgia.	Feb. 16, 1924
GRIMSBY, Ont. Water Commission, W. B. Smith, Chief Engineer & Supt., Grimsby, Ont., Can.	Feb. 23, 1927
GUELPH, ONT. H. S. Nicklin, City Engineer, City Hall, Guelph, Ont., Canada	Mar. 25, 1924
GULF STATES UTILITIES CO. Louisiana Division, Lake Charles, La.	Apr. 29, 1910
GUNTERSVILLE WATER WORKS. J. L. McIntyre, Supt., Guntersville, Ala	Feb. 25, 1927
HONOLULU CITY AND COUNTY, DEPARTMENT OF PUBLIC WORKS. Kapiolani Building, Honolulu, T. H.	Aug. 20, 1927
HOPKINSVILLE WATER CO. Hopkinsville, Ky	**Apr. 23, 1915**
HOT SPRINGS WATER CO. Hot Springs, Ark	**Mar. 23, 1920**
IDAHO SURVEYING & RATING BUREAU. P. O. Box 1059, Boise, Idaho	Feb. 9, 1924
ILION BOARD OF WATER COMMISSIONERS. Ilion, N. Y.	Mar. 31, 1924
ILLINOIS INSPECTION BUREAU. 108 E. Ohio Street, Chicago, Ill.	Jan. 30, 1924
ILLINOIS POWER & LIGHT CORP. Compton Bldg., St. Louis, Mo.	Mar. 26, 1923
INDIANA STATE BOARD OF HEALTH, WATER & SEWAGE DEPARTMENT. Lewis S. Finch, Director, Indianapolis, Ind.	June 15, 1926
INTERSTATE PUBLIC SERVICE CO. New Albany, Ind.	Feb. 10, 1910
IRONWOOD WATER DEPT. Dow I. Sears, Ironwood, Mich.	May 17, 1920
JOHNSON CITY WATER DEPT. Arthur J. Merrill, Supt., Johnson City, N. Y.	Sept. 30, 1925
KANSAS CITY Power & LIGHT CO. Glen S. Morris, Supervisor, Valuation Department, 1330 Grand Ave., Kansas City, Mo.	Aug. 24, 1925
KANSAS CITY, MO. Director of the Water Dept., City Hall, Kansas City, Mo.	Feb. 8, 1915
KENNEBEC WATER DIST., TRUSTEES. George K. Boutelle, Treasr., Waterville, Maine	May 12, 1912
KENTUCKY STATE BOARD OF HEALTH. F. C. Dugan, Dctr. Bur. San. Eng., 532 W. Main St. Louisville, Ky.	Feb. 5, 1915
KENTUCKY UTILITIES CO.. 1350 Starks Bldg., Louisville, Ky.	Feb. 13, 1905
KITCHENER WATER COMMISSION. Kitchener, Canada	**Feb. 17, 1920**
KNOXVILLE WATER DEPT. City Hall Park Building, Knoxville, Tenn	May 23, 1923
LAJUNTA, CITY OF, COLORADO	Sept. 18, 1926
LAKE FOREST WATER DEPARTMENT. J. C. McNicol, Mgr., City Hall, Lake Forest, Ill.	May 24, 1927
LANETT COTTON MILL. M. R. Wallis, West Point, Georgia	Mar. 1, 1924
LAWRENCE, KANS. Engineering Department, C. T. Hough, City Engr. & Wtr. Supt., City Hall, Lawrence, Kansas	Feb. 17, 1927
LEAMINGTON, ONTARIO, CANADA, CORPORATION OF TOWN OF	May 30, 1925
LEWISTOWN-REEDSVILLE WATER CO. Lewistown, Pa.	May 14, 1922

LINCOLN CITY WATER & LTG. DEPT. City Hall, Lincoln, Neb.	Mar. 6, 1919
LOCKPORT BOARD OF WATER COMMISSIONERS. Lockport, N. Y.	Apr. 9, 1924
LONDON, CANADA, PUBLIC UTILITIES COMMISSION	Apr. 9, 1909
LOS ANGELES, CALIF. William Mulholland, Chf. Engr., Bureau of Water Works & Supply, Box 497, Los Angeles, Calif.	Apr. 18, 1910
LOS ANGELES WATER SERVICE CO. J. L. Munson, Pres., 214 E. 96th St., Los Angeles, Calif.	Oct. 27, 1925
LOUISVILLE WATER CO. 435 So. Third St., Louisville, Ky.	Apr. 9, 1909
LOVELAND, COLORADO, CITY OF	Apr. 13, 1926
MADERA, CALIF. Municipal Water Works, O. C. Owens, Supt., City Hall, Madera, Calif.	June 17, 1926
MAHONING VALLEY WATER CO. Struthers, Ohio	July 26, 1916
MALMO BYGGNADSKONTOR. Alfred Jerden, Chf. Engr., Malmo, Sweden	July 23, 1921
MARION WATER CO. George Whysall, Treas. & Gen. Mgr., Marion, Ohio	Mar. 3, 1917
MASSILLON WATER SUPPLY CO. Watson A. Dark, Supt., Massillon, O.	June 8, 1921
MEIGS WATER CO. C. M. Herminy, Gen. Mgr., Middleport, Ohio	Feb. 23, 1924
MEMPHIS, TENN. Board of Water Commissioners, James Sheahan, Gen. Supt., Memphis, Tenn.	Apr. 2, 1909
MERRITTON, ONT. Water Works Department, Public Utilities Commission, Merritton, Ont., Canada	June 17, 1926
METROPOLITAN BD. WATER SUPPLY AND SEWAGE. 341 Pitt St., Sydney, N. S. W., Australia	Aug. 31, 1909
MIDDLETOWN WATER WORKS. G. Allen Schaefer, Middletown, Conn.	June 8, 1921
MIDLAND PUBLIC UTILITIES COMM. P. O. Box 548, Midland, Ont., Canada	Mar. 16, 1927
MILL VALLEY, CALIF. H. C. Symonds, 147 Monte Vista Ave.	Nov. 15, 1926
MILLVILLE WATER CO. Millville, N. J.	Jan. 11, 1916
MINNEAPOLIS COMMITTEE ON WATER WORKS. Wm. R. Young, Registrar, Minneapolis, Minn.	June 17, 1920
MOLINE WATER DEPARTMENT, City Hall, Moline, Ill.	Jan. 29, 1916
MONTCLAIR BUREAU OF WATER SUPPLY. Montclair, New Jersey	Apr. 27, 1925
MOUNT CARMEL WATER CO. Mount Carmel, Pa.	May 7, 1904
MOUNT HOLLY WATER CO. Mount Holly, N. J.	Apr. 30, 1924
MUNICIPAL WATER CO. OF ILLINOIS. C. B. Shapker, President, 134 S. LaSalle St., Chicago, Ill.	May 28, 1926
MUSCATINE WATER TRUSTEES. Muscatine, I.	May 9, 1921
NEGOCIADO DE ACUEDUCTOSY, ALCANTARILLADO. Secretaria de Obras Publicas, Havana, Cuba	Apr. 10, 1926
NEW JERSEY DEPT. CONSERVATION AND DEVELOPMENT. H. T. Critchlow, H. E., State House, Trenton, N. J.	Jan. 26, 1922
NEW JERSEY WATER CO. 521 Federal St., Camden, N. J.	Jan. 6, 1927
NEW MEXICO POWER CO. Santa Fe, N. Mex.	Mar. 12, 1924
NEW ROCHELLE WATER CO. 514 Main St., New Rochelle, N. Y.	Jan. 6, 1927
NORTH DAKOTA STATE REGULATORY DEPARTMENT. R. O. Baird, Box 653, Bismarck, N. Dak.	Jan. 19, 1926
NORTH JERSEY DISTRICT WATER SUPPLY COMM. 20 Clinton Street, Newark, N. J.	May 26, 1925

Northampton Consolidated Water Co. 102 So. 3rd St., Easton, Pa.	Dec. 5, 1915
Norton, Va. Water Dept., E. H. Ruehl, Mgr., Norton, Va.	Jan. 10, 1925
Ohio Inspection Bureau. Hartman Bldg., Columbus, Ohio.	Jan. 30, 1924
Old Dominion Water Corp. Box 33-A, Hopewell, Va.	Jan. 17, 1922
Omaha, Nebr. Metropolitan Utilities District, Utilities Bldg., Harney at Eighteenth St., Omaha, Nebr.	Apr. 28, 1912
Oswego Department of Water. Oswego, N. Y.	June 1, 1921
Owego Water Works Co. Owego, N. Y.	Apr. 16, 1914
Pasadena Water Dept. S. B. Morris, Chief Engineer, 602 Central Bldg., 30 N. Raymond Ave., Pasadena, Calif.	Oct. 14, 1924
Peninsula Water Co. Wm. F. Turnbull, Gen. Mgr., 211 Second Ave., San Mateo, Calif.	Oct. 29, 1926
Pennichuck Water Works. 11 High St., Nashua, N. H.	Oct. 30, 1914
Pennsylvania State Water Corp. Reeves J. Newsom, Pres. 222 N. 3rd St., Harrisburg, Pa.	May 26, 1927
Peoria Water Works Co. Peoria, Ill.	Jan. 6, 1927
Peterborough, Ont. R. L. Dobbin, Waterworks Supt., 622 George St., Peterborough, Ont., Can.	May 2, 1911
Pineville Water Supply Co. T. F. Gibson, President, Pineville, Ky.	May 12, 1925
Pontiac, Mich. Dept. of Water Supply, G. D. Kennedy, Civil Engr., Pontiac, Mich.	June 6, 1927
Portland Dept. of Public Utilities. Room 302, City Hall, Portland, Ore.	Dec. 17, 1917
Poughkeepsie Board of Public Works. Water Department, Poughkeepsie, N. Y.	Dec. 11, 1912
Providence, R. I. M. H. Bronson, Comm. of Pub. Wks., Water Maintenance Dept. City Hall, Providence, R. I.	Oct. 9, 1924
Quincy Water Works Commission. 314 Maine St., Quincy, Ill.	Apr. 4, 1927
Reading Bureau of Water. Room 209, City Hall, Reading, Pa.	Mar. 20, 1916
Regina, Sask., Waterworks Department. City Hall, Regina, Sask., Canada.	Apr. 4, 1924
Riverside, Calif. Water Department.	July 22, 1926
Roanoke Water Works Co. Francis W. Collins, Cons. Engr., 452 Lexington Ave., New York, N. Y.	Dec. 3, 1904
Rome. Department of Public Works, Bureau of Water, Rome, N. Y.	Apr. 25, 1922
Saginaw Water Dept. Saginaw, Mich.	Apr. 12, 1904
St. Mary's Ont., Board of Water, Light & Heat Comn., Box 333, St. Marys Ont., Canada.	Nov. 3, 1919
St. Thomas, Ont. Colonel A. F. McLachlin, F.C.I.C., Ross Street, St. Thomas, Ont., Canada.	Apr. 11, 1909
Salina Water Department. H. L. Brown, Supt., Salina, Kansas	Feb. 17, 1927
Salt Lake City Water Dept. H. K. Burton, Supt., Salt Lake City, Utah.	Feb. 17, 1920
San Jose Water Co. Joseph R. Ryland, Pres., San Jose, Cal.	Apr. 21, 1913
Sandusky, Ohio, O. F. Schoepfle, Filtration Plant, Meigs St., Sandusky, Ohio.	June 9, 1921
Sandwich Water Board. Box 153, Sandwich, Ont., Canada	Feb. 25, 1927
Santa Monica, Calif. Water Department, City Hall, Santa Monica, Calif.	June 5, 1926
Scranton Gas and Water Co. 135 Jefferson Ave., Scranton, Pa.	June 3, 1912

Sea Breeze & Vicinity Wtr. Comn. Henry Fleig, Sect., Point Pleasant, Monroe Co., N. Y.	Feb. 23, 1920
Sheboygan Board of Water Comnrs. City Hall, Sheboygan, Wis.	June 21, 1920
Shenandoah Commissioners of Water Works. Shenandoah, Pennsylvania.	May 19, 1924
Shenango Valley Water Co. 24 So. Dock St., Sharon, Pa.	Apr. 10, 1922
Sherrill-Kenwood Water Commission. Stephen R. Leonard, Chairman, Kenwood, Oneida, N. Y.	Apr. 24, 1921
Sioux Falls Water Works. R. Rees, Supt., Sioux Falls, S. Dak.	May 24, 1927
Spokane, Wash., Superintendent Water Division. Room 303, City Hall, Spokane, Wash.	Apr. 5, 1912
Suburban Water Co. of Allegheny County. Verona, Pa.	Apr. 10, 1909
Sumpwams Water Works Co. J. C. Robbins, Pres., Babylon, N. Y.	June 15, 1926
Sweetwater Water Company. National City, Calif.	June 15, 1926
Syracuse Bureau of Water. Syracuse, N. Y.	Jan. 16, 1923
Tallassee Power Co. Badin, N. C.	Nov. 15, 1924
Toronto, Ohio, Board of Public Affairs. J. B. Thompson, Supt., Toronto, Ohio	Feb. 23, 1924
Totowa, Borough of. Totowa, N. J.	Oct. 20, 1920
Trenton Water Works. Trenton, N. J.	May 8, 1909
Trotter Water Co. C. L. Farson, Supt., P. O. Box 308, Uniontown, Pa.	July 26, 1921
Troy Bureau of Water. William Luby, Troy, N. Y.	May 28, 1924
Truckee River Power Co. Reno, Nev.	Feb. 4, 1913
Urban Water Supply Co. Maurice & Borden Ave., Maspeth, L. I.	Oct. 20, 1912
Utrechtsche Waterleiding. Maatschappij, Utrecht, 15 Predikheerenkerkhof, Holland.	Nov. 9, 1922
Vallejo City Water Dept. Alf E. Edgcumbe, City Clerk, City Hall, Vallejo, Calif.	June 11, 1924
Waco Water Works. 617 Washington Ave., Waco, Texas	Apr. 16, 1910
Wahiawa Water Co., Ltd. Wahiawa, Oahu, T. H.	Apr. 20, 1923
Watertown Water Works. Watertown, N. Y.	June 8, 1909
Welland, Ont., Board of Water Commission. L. H. Pursel, Chairman, Welland, Ont., Can	May 7, 1920
West Newton Water Co. West Newton, Pa.	May 24, 1922
West Virginia Utilities Co. Morgantown, W. Va.	Feb. 23, 1924
West Virginia Water Service Co. H. M. Cogan, Genl. Mgr., Charleston, W. Va.	Sept. 4, 1911
Western New York Water Co. 704 Electric Building, Buffalo, N. Y.	Apr. 15, 1913
Whitby, Ont., Public Utility Commission. George W. P. Every, Supt., Municipal Waterworks Dept., Whitby, Ont., Canada.	Feb. 23, 1924
White Deer Mountain Water Co. 114 So. Front St., Milton, Pa.	May 5, 1914
White Plains Dept. of Public Works. William I. Collyer, Water Supt., White Plains, N. Y.	July 31, 1916
Whittier, Calif. M. R. Bower, City Water Superintendent, City Hall, Whittier, Calif.	Dec. 16, 1926
Williamsport Water Co. 330 Pine St., Williamsport, Pa.	Apr. 15, 1907
Windsor Ont., Water Commissioners. Windsor, Ont.	Feb. 19, 1923
Winnetka, Ill., Village of	June 21, 1920
Winona Board of Municipal Works. Winona, Minnesota	Dec. 11, 1922

ASSOCIATE MEMBERS

ALLIS-CHALMERS MFG. CO. Milwaukee, Wis.	June 24, 1905
ALUMINATE SALES CORPORATION. Union Stock Yards, Chicago, Ill.	June 21, 1926
AMBURSEN CONSTRUCTION CO., INC. Grand Central Terminal Bldg., New York, N. Y.	Jan. 29, 1921
AMERICAN BRASS CO., THE. Sales Dept., Waterbury, Conn.	Aug. 10, 1922
AMERICAN CAST IRON PIPE CO. Birmingham, Ala.	July 18, 1907
"AMERICAN CITY." 443 Fourth Ave., New York, N. Y.	May 25, 1918
AMERICAN FOUNDRY & MFG. CO. 10th, 11th, Hebertt and Wright Sts., St. Louis, Mo.	May 12, 1908
AMERICAN ROLLING MILL CO. R. C. Beam, Development Dept., Sales Div. Middletown, Ohio.	Jan. 31, 1927
AMERICAN STEEL & WIRE CO. Chemical & Color Dept., 208 South LaSalle St., Chicago, Ill.	June 24, 1903
AMERICAN SEAMLESS TUBE CORPORATION OF CALIFORNIA. 710 Petroleum Securities Bldg., Los Angeles, Calif.	Sept. 12, 1927
AMERICAN WATER SOFTENER CO. Lehigh Ave. & Fourth St., Philadelphia, Pa.	July 14, 1923
AMERICAN WELL WORKS, THE. Aurora, Illinois.	Mar. 21, 1923
AMERICAN ZEOLITE CORP. East 11th St. & Fifth Ave., Paterson, N. J.	May 28, 1924
ARNOLD, HOFFMAN & CO., INC. 18th Floor, 350 Madison Ave., New York, N. Y.	Nov. 21, 1913
ART CONCRETE WORKS. Mfrs. Meter Boxes, P. O. Box 417, Pasadena, Cal.	Dec. 13, 1920
ASPHALTO-CONCRETE CORP. 1440 Broadway, New York, N. Y.	June 6, 1927
AUTOMATIC CONE VALVE CO. 32 W. Randolph St., Chicago, Ill.	Mar. 13, 1925
AUTOMATIC PRIMER CO. F. H. Bradford, Pres., 111 W. Washington St., Chicago, Ill.	Apr. 4, 1924
BABCOCK & WILCOX CO. J. B. Romer, Chemist, Bayonne, N. J.	May 28, 1924
BADGER METER MFG. CO. 841–7 Thirtieth St., Milwaukee, Wis.	June 8, 1904
BAKER IRON WORKS. H. S. Hitchcock, V. P. & Gen. Mgr., 950 N. Broadway, Los Angeles, Calif.	Sept. 27, 1926
BARBER-GREENE CO. Aurora, Ill.	Jan. 26, 1926
BAYARD, M. L. 20th St. & Indiana Ave., Philadelphia, Pa.	Mar. 31, 1922
BIGGS BOILER WORKS COMPANY. Mr. F. G. Sherbondy, Sect.-Treas., Bank & Williams Streets, Akron, Ohio.	Apr. 28, 1925
BIRCH MANUFACTURING CO. 1521–1523 Sedgwick St., Chicago, Ill.	May 11, 1916
BOURBON COPPER & BRASS WORKS CO. 618 E. Front St., Cincinnati, Ohio.	Apr. 17, 1884
BOWLER FOUNDRY CO. 1688 Columbus Road, Cleveland, Ohio.	July 6, 1922
BRIGGS BITUMINOUS COMPOSITION CO., INC. 33 Rector St., New York, N. Y.	Nov. 6, 1924
BUCKEYE TRACTION DITCHER CO. C. D. Royce, Sales & Avd. Mgr., Findlay, Ohio.	May 26, 1920

Buffalo Meter Co. 2917 Main St., Buffalo, N. Y.	June 27, 1905
Builders Iron Foundry, 9 Codding St., Providence, R. I.	June 18, 1901
Burroughs Adding Machine Co. A. S. Trew, Public Utilities Sale, Second Boulevard, Detroit, Mich.	Mar. 30, 1926
Byers, A. M., Co. 235 Water St., Pittsburgh, Pa.	June 15, 1921
Caldwell Co., Geo. A. Mattapan Square, Boston, Mass.	June 6, 1927
California Corrugated Culvert Company. 5th & Parker Sts., West Berkeley, Calif.	Aug. 24, 1927
California Meter Co. 687–89 So. Clarance St., Los Angeles, Calif.	June 6, 1927
"Canadian Engineer." Church & Court Sts., Toronto, Ont., Can.	May 31, 1916
Cement Gun Construction Company. 58 Sutter St., San Francisco, Calif.	Oct. 13, 1926
Cement Lined Pipe Co. 591 Washington St., Lynn, Mass.	May 28, 1924
Central Foundry Co. Graybar Bldg., 420 Lexington Ave., New York, N. Y.	June 24, 1903
Chapman Valve Mfg. Co. Indian Orchard, Mass.	Apr. 16, 1884
Chicago Bridge & Iron Works. 37 W. Van Buren St., Chicago, Ill.	June 15, 1908
Chicago Chemical Co. 6216 W. 66th Place, Chicago, Ill.	June 6, 1927
Clark, H. W., Co. Box 563, Mattoon, Ill.	May 12, 1908
Clow, J. B., & Sons, Harrison & Franklin Sts., Chicago, Ill.	Apr. 27, 1885
Coffin Valve Co., Neponset, Mass.	May 21, 1922
Cohoes Rolling Mill Co. Canvass & Cortland Sts., Cohoes, N. Y.	Jan. 2, 1924
Coldwell-Wilcox Co. Newburgh, N. Y.	Apr. 17, 1914
Colorado Fuel & Iron Co. Denver, Colo.	June 7, 1897
Columbian Iron Works. Chattanooga, Tenn.	Apr. 4, 1910
Cook, A. D., Inc. Manufacturer of Deep Well Pumps & Strainers, Lawrenceburg, Ind.	June 14, 1914
Copper & Brass Research Assoc. Wm. G. Schneider, 25 Broadway, New York, N. Y.	Aug. 28, 1923
Cramer & Co., R. W. Inc. 136 Liberty St., New York, N. Y.	Mar. 29, 1927
Crane Company. A. M. Houser, Engineer of Product, 836 S. Michigan Ave. Chicago, Ill.	Jan. 25, 1926
Crane, Theron I. Vice Pres., Talbot Non-Corrosive Linings Co., 1114 Widener Bldg., Philadelphia, Pa.	Mar. 27, 1926
Darling Valve & Man'fg. Co. Williamsport, Penna.	May 12, 1908
Dayton-Dowd Co. Quincy, Ill.	July 5, 1922
Dearborn Chemical Co. 310 So. Michigan Ave., Chicago, Ill.	June 6, 1927
De Laval Steam Turbine Co. H. L. Watson, Sales Mgr., Trenton, N. J.	Nov. 23, 1917
Donaldson Iron Co. Emaus, Lehigh Co., Pa.	Nov. 23, 1917
The Dorr Co., Inc. 247 Park Ave., New York, N. Y.	June 1, 1927
Dravo-Doyle Co. J. D. Berg, Vice-Pres., Diamond Bank Bldg., Pittsburgh, Pa.	May 12, 1914
Dresser, S. R., Mfg. Co. Mfgr. Pipe Couplings & Sleeves, Bradford, Pa.	June 7, 1904
Drummond, McCall & Co., Ltd. Toronto, Ont., Canada	Mar. 5 1921
du Pont de Nemours, E. I. & Co. W. F. Donohoe, Sales Mgr., 3500 Grays Ferry Road, Philadelphia, Pa.	May 12, 1908
East Jersey Pipe Co. 7 Dey St., New York, N. Y.	July 10, 1906
Eddy Valve Co. Waterford, N. Y.	June 26, 1886

Edson Manufacturing Corp. 375 Broadway, Boston '11', Mass.	Mar. 21, 1923
Electric Welding Co. of America. Geo. S. Levine, 744 Court St., Brooklyn, N. Y.	Mar. 19, 1926
Electro Bleaching Gas Co. 9 E. 41st St., New York, N. Y.	Apr. 2, 1913
"Engineering & Contracting." 221 E. 20th St., Chicago, Ill.	May 13, 1918
"Engineering News-Record." 10th Ave. at 36th St., New York, N. Y.	May 31, 1918
Everlasting Paint & Sales Co. 704 Sun Finance Bldg., Los Angeles, Calif.	Nov. 27, 1926
Fairbanks Company. 416 Broome St., New York, N. Y.	Mar. 30, 1926
Fairbanks, Morse & Co. Research Division, Chicago, Ill.	Mar. 23, 1925
Farnan Brass Works Co. 1104 Center St., Cleveland, Ohio	May 18, 1892
Federal Meter Corp., East Orange, N. J.	May 23, 1923
Fleischmann Co. Peekskill, N. Y.	June 15, 1922
Ford Meter Box Co. Wabash, Ind.	May 12, 1908
Forni Manufacturing Co. 1377 62nd St., Oakland, Cal.	Aug. 28, 1924
Fox, John, & Co. 233 Broadway, New York City, N. Y.	June 8, 1909
Gamon Meter Co. Newark, N. J.	May 19, 1920
General Chemical Co. 300 W. Adams St., Chicago, Ill.	June 11, 1902
General Electric Co. Mr. Lee F. Adams, Industrial Engineering Dept., Schenectady, N. Y.	June 1, 1921
General Office Equipment Corp. E. A. Norman, Sales Mgr., 342 Madison Ave., New York, N. Y.	Apr. 30, 1923
Giant Manufacturing Co. Council Bluffs, Iowa	Jan. 5, 1925
Gillespie, T. A., Co. 7 Dey St., New York, N. Y.	June 7, 1904
Glamorgan Pipe & Foundry Co. Lynchburg, Va.	Nov. 6, 1907
Glauber Brass Mfg. Co. Platt Ave. & East 79th St., Cleveland, Ohio	May 13, 1914
Greenberg's Sons, M. Fire Hydrant & Valve Mfrs., 765 Folsom St., at Alice St., San Francisco, Cal.	Sept. 30, 1924
Griffin Fdy. & Mfg. Co. M. N. Griffin, Pres., Rome, Ga.	June 30, 1926
Grinnell Co., Inc. P. O. Box 336, Charlotte, N. C.	May 17, 1923
Gurley, W. & L. E. 514 Fulton St., Troy, N. Y.	Apr. 16, 1919
Hammersmith, F. A. Dist. Sales Mgr., Bunker Hill Smelter & N. W. Lead Co., 1018 Crocker Bldg., San Francisco, Calif.	June 17, 1926
Hankin, Francis, & Co., Ltd. 598–604 Union Ave., Montreal, Canada	June 19, 1920
Hanks Co., Fred W. Fred W. Hanks, Mgr., 10624 St. Clair Ave., Cleveland, Ohio	June 5, 1926
Hardesty Mfg. Co., R. 31st & Blake Sts., Denver, Colo.	Mar. 31, 1925
Hays Mfg. Co. Erie, Pa	Mar. 15, 1882
Hendrie & Bolthoff Mfg. & Supply Co. James S. Smith, 1635 Seventeenth St., Denver, Colo.	Mar. 22, 1926
Hersey Mfg. Co. South Boston, Mass.	July 14, 1887
Hill, Hubbell & Co. 115 Davis St., San Francisco, Calif.	Oct. 13, 1926
Hooker Electrochemical Co. G. F. Reale, 25 Pine St., New York, N. Y.	July 7, 1920
Hungerford & Terry, Inc. Clayton, N. J.	Dec. 31, 1926
Hydraulic Development Co. 296 Boylston St., Boston, Mass.	May 12, 1925
Ingersoll, Rand Co. 11 Broadway, New York City	Oct. 31, 1922
International Filter Co. 329–337 25th Place, Chicago, Ill.	Nov. 3, 1915
Interstate Machinery & Supply Co. 1006–8–10 Douglas St., Omaha, Nebr.	May 31, 1927

Byron Jackson Pump Mfg. Co. West Berkeley, Cal........	Sept. 30, 1924
Jenkins Bros., Ltd. 103 St. Remi St., Montreal, Canada...	May 20, 1920
Johnson, Edward E., Inc. 2304 Long Ave., St. Paul, Minn..	May 17, 1922
Jones, James, Co. W. B. Jones, Secy., 201 Leroy St., Los Angeles, Cal....................................	Oct. 20, 1921
Kalbfleisch Corporation. 200 Fifth Ave., New York, N. Y.	June 8, 1906
Kelly Well Co. 112½ E. Third St., Grand Island, Nebr.....	Jan. 7, 1924
Kennedy Valve Mfg. Co. M. E. Kennedy, Treas., Elmira, N. Y..	Mar. 24, 1911
Keystone Driller Company. Will R. Cook, Mgr., Pump Department, Beaver Falls, Pa.........................	June 1, 1927
Kimball, Frank J., Co. Box 27, Station K, Los Angeles, Calif..	Sept. 18, 1925
Kingsbury Machine Works, Inc. 4324 Tackawanna St., Frankford, Philadelphia, Pa..........................	June 1, 1927
La Motte Chemical Products Co. McCormick Bldg., Baltimore, Md.......................................	May 14, 1926
Layne and Bowler Co. Memphis, Tenn...................	June 5, 1916
Lead Lined Iron Pipe Co., The. Wakefield, Mass..........	Oct. 5, 1898
Leadite Company, Inc., The. Land Title Building, Philadelphia, Pa..	Feb. 10, 1910
Lock Joint Pipe Co. Box 21, Ampere, N. J.	Oct. 5, 1915
Los Angeles Valve & Fittings Co. 2741 Compton Ave., Los Angeles, Calif..................................	Oct. 13, 1926
Ludlow Valve Mfg. Co. Troy, N. Y......................	Mar. 5, 1882
Lynchburg Foundry Co. Lynchburg, Va..................	June 6, 1916
McCloskey Torch Co. 3343 Collingwood Ave., Toledo, Ohio.	June 6, 1927
McWane Cast Iron Pipe Co. Birmingham, Ala...........	Apr. 23, 1923
Mabbs Hydraulic Packing Co. 431 S. Dearborn St., Chicago, Ill...	May 7, 1923
Machinery Pipe & Supply Co. 200—9th, San Diego, Calif.	Nov. 15, 1926
MacLean, Hugh C., Publications, Ltd. Pblr. Trade & Tech. Jls., 347 Adelaide St. W., Toronto, Ont., Canada...	June 2, 1920
Mathieson Alkali Works, Inc. 250 Park Ave., New York, N. Y..	Mar. 16, 1920
Michigan Valve & Foundry Co. 3631 Parkinson Ave., Detroit, Mich...	June 7, 1919
Mississippi Lime & Material Co. Mr. C. C. Schmoeller, Sales Mgr., Alton, Illinois..........................	June 20, 1925
Modern Iron Works. Quincy, Ill.........................	June 27, 1905
Montague Pipe & Steel Co. 803 Hobart Building, San Francisco, Calif.....................................	Dec. 31, 1922
Moore Brothers. 415 Virginia Ave., Elkhart, Ind..........	Nov. 4, 1926
Morris Machine Wks. Baldwinsville, N. Y................	July 31, 1923
Mueller Brass Co. O. B. Mueller, Port Huron, Mich.....	June 6, 1927
Mueller Co. Decatur, Ill..................................	Mar. 15, 1882
Multiplex Mfg. Co. Multiplex Bldg.. Berwick, Pa........	May 7, 1916
Murray Iron Works Co. Burlington, Iowa................	Mar. 6, 1923
National Cast Iron Pipe Co. E. E. Linthicum, Pres., Birmingham, Ala.......................................	May 17, 1916
National Iron Corpn., Ltd. Cherry St., Toronto, Ont., Canada..	Oct. 22, 1921
National Iron Works. Leo G. Moore, Mgr., Foot of 7th St., San Diego, Calif..................................	Nov. 15, 1926
National Meter Co. 299 Broadway, New York, N. Y.......	Mar. 15, 1882
National Tube Co. W. L. Schaeffer, 1902 Frick Bldg., Pittsburgh, Pa...	May 18, 1921

National Water Main Cleaning Co. 50 Church St., New York, N. Y. .... July 10, 1906
Nelson, Jos. E., & Sons. Contractors, 3240 S. Michigan Ave., Chicago, Ill. .... Sept. 7, 1919
Neptune Meter Co. 50 East 42nd St., New York, N. Y. .... Aug. 22, 1894
Nicoll, & Company, B., Inc. 294 Madison Ave., New York, N. Y. .... Mar. 27, 1925
Northern Gravel Co. G. H. Boynton, Pres., American Savings Bk. Bldg., Muscatine, Iowa .... Jan. 31, 1927

Ohio Drilling Co. Thos. O. Poe, Massillon, Ohio .... June 17, 1926
Ohio Varnish Company. Mr. J. P. Deery, 8709 Kinsman Road, Cleveland, Ohio .... May 29, 1925

Pacific Pump Works. 350 Bickett Street, Huntington Park, Calif. .... Aug. 8, 1927
Parker Appliance Co. 10320 Berea Rd., Cleveland, Ohio .... May 11, 1927
Parsons Company. Newton, Iowa .... Dec. 10, 1925
Parsons, Klapp, Brickerhoff & Douglas. Consulting Engineers, 84 Pine St., New York, N. Y. .... July 26, 1922
Peerless Pump Co., P. O. Box 493, Massillon, Ohio .... June 6, 1927
Penstock Construction Co. F. M. Strecker, President, Sharon, Pa. .... Nov. 25, 1925
Pennsylvania Salt Mfg. Co. Widener Building, Philadelphia, Pa. .... June 24, 1903
Permutit Co. 440 Fourth Ave., New York, N. Y. .... Mar. 11, 1914
Philadelphia Suburban Water Co. 762 Lancaster Ave., Bryn Mawr, Pa. .... May 1, 1909
Philbrook Spring Pipe Clamp Co. Mr. C. B. Meskimons, Mgr., 629 E. 12th St., Los Angeles, Calif. .... Nov. 6, 1924
Phoenix Meter Co. 5906 Amboy Rd., Princes Bay, S. I., N. Y. .... May 11, 1927
Pitometer Co. 50 Church St., New York, N. Y. .... July 10, 1906
Pittsburgh-Des Moines Steel Co. Pittsburgh, Pa. .... Apr. 14, 1914
Pittsburgh Equitable Meter Co. Wilkinsburg Branch P. O., Pittsburgh, Pa. .... June 15, 1898
Pittsburgh Testing Laboratory. P. O. Box 1115, Pittsburgh, Pa. .... May 8, 1915
Pollard, Joseph G., Co., Inc. 142 Raymond St., Brooklyn, N. Y. .... Apr. 30, 1926
Pomona Mfg. Co. 206 E. Commercial St., Pomona, Calif. .... May 24, 1927
Portland Cement Association. 33 W. Grand Ave., Chicago, Ill. .... Oct. 23, 1917
"Public Works." 243 West 39th St., New York, N. Y. .... May 25, 1918

R. U. V. Co. 7 Burritt Ave., South Norwalk, Conn. .... June 6, 1917
Raymond Equipment Co. P. O. Box 1613, 1017 Piedmont Road, Charleston, W. Va. .... Jan. 11, 1926
Rensselaer Valve Co. Troy, N. Y. .... May 12, 1890
Republic Flow Meters Co. 2240 Diversey Parkway, Chicago, Ill. .... Jan. 10, 1927
Rex Tapping Machine Co. L. M. Biddle, 919 Sonoma St., Vallejo, Calif. .... Oct. 27, 1925
Rich Steel Products Company. 3855 Santa Fe Ave., Los Angeles, Calif. .... Sept. 26, 1927
Rick, Edward L. Pres., Rick Co., 2220 W. Anaheim St., Long Beach, Calif. .... Oct. 25, 1926
Riter Conley Co. Box 939, Pittsburgh, Pa. .... June 11, 1924
Roberts Filter Mfg. Co. Darby, Philadelphia, Pa. .... Mar. 23, 1910
Ross Valve Mfg. Co., Inc. Oakwood Ave., Troy, N. Y. .... Apr. 18, 1891

S. E. T. Valve & Hydrant Co. 50 Church St., New York, N. Y.	Apr. 14, 1924
Sanitation Corp. Graybar Bldg., Grand Central Terminal, New York, N. Y.	Apr. 27, 1915
Savage, W. J., Co. Knoxville, Tenn.	May 31, 1919
Scofield Engineering Co. 1324 Commercial Trust Bldg., Philadelphia, Pa.	June 7, 1921
Simplex Valve & Meter Co. 5722 Race St., Philadelphia, Pa.	May 14, 1914
Sims Pump Valve Co. 2 Rector St., New York, N. Y.	Mar. 23, 1922
Sirch, C. W. Sirch Filters, Suite 300–301 Lankersheim Bldg., Los Angeles, Calif.	Sept. 25, 1923
Sixbey, C. C. Chamber of Commerce Bldg., Los Angeles, Calif.	Nov. 15, 1926
Smith, A. P. Mfg. Co. East Orange, N. J.	June 7, 1897
Sparling, R. W. Manufacturer of Water Measuring Equipment, 945 North Main St., Los Angeles, Calif.	Nov. 10, 1925
Steel Tank & Pipe Co. of Calif. 1100 Fourth St., Berkeley, Calif.	Aug. 23, 1926
Sterling Pump Works, Inc. 646 S. California St., Stockton, Calif.	Jan. 19, 1926
Stone & Tar Products Co. 97 So. 6th St., Brooklyn, N. Y.	Aug. 28, 1925
Stone & Webster, Inc. Dana M. Wood, 147 Milk Street, Boston, Mass.	May 29, 1925
Street Lighting & Equipment Co. Hewitt Davenport, Mgr., 610 Alexander Bldg., San Francisco, Calif.	May 17, 1927
Sullivan Machinery Co. 122 S. Michigan Ave., Chicago, Ill.	Mar. 31, 1915
Sydnor Pump & Well Co., Inc. Thos. G. Sydnor, Pres., Richmond, Va.	Dec. 13, 1924
Taylor, W. P., Co. 218 Ellicott Square, Buffalo, N. Y.	Mar. 15, 1882
Thompson, William H., Co., Inc. Water Main Cleaning Contrs., 501 Linwood Ave., Buffalo, N. Y.	Jan. 10, 1925
Thomson Meter Co. 50 E. 42nd St., New York, N. Y.	Apr. 15, 1891
Traverse City Iron Works. Box 67, Traverse City, Mich.	Apr. 29, 1924
Union Water Meter Co. 33 Hermon St., Worcester, Mass.	Mar. 15, 1882
United Casting Company. 824 Wilson St., Los Angeles, Calif.	Sept. 7, 1926
United Lead Co., 111 Broadway, New York, N. Y.	May 12, 1908
United States Cast Iron Pipe & Foundry Co., 1421 Chestnut St., Philadelphia, Pa.	June 11, 1892
United States Silica Co. 122 So. Michigan Ave., Chicago, Ill.	Apr. 27, 1927
Van Gilder Water Meter Co. Chester & Grant Aves., Pleasantville, N. J.	Mar. 31, 1924
Victaulic Company of America, 26 Broadway, New York, N. Y.	Apr. 13, 1926
Virginia Mach. & Well Co., Inc. Chas. F. Cole, Pres., 1319 E. Main St., Richmond, Va.	Apr. 20, 1926
Vogt Brothers Mfg. Company. 1402 West Main Street, Louisville, Ky.	May 12, 1925
Voorhees Rubber Mfg. Co. 20–56 Bostwick Avenue, Jersey City, N. J.	Jan. 4, 1923
Wailes Dove-Hermiston Corp. 17 Battery Place, New York, N. Y.	Mar. 13, 1925
Wallace & Tiernan Co., Inc. Box 178, Newark, N. J.	Apr. 23, 1915

WARREN FOUNDRY & PIPE CO. 11 Broadway, New York, N. Y.	Mar. 4, 1911
"WATER WORKS ENGINEERING." 225 West 34th St., New York, N. Y.	June 28, 1919
WATER WORKS EQUIPMENT CO. 50 Church St., Rooms 1950–51, New York, N. Y.	July 10 1906
WATEROUS FIRE ENGINE WORKS. 80 E. Filmore Avenue, St. Paul, Minn.	May 20, 1925
WATERPROOF PAINT CO. Eugene R. Oden, Lankershim, Calif.	May 24, 1927
WESTERN CONCRETE PIPE CO. P. O. Box 355, Los Angeles, Calif.	Oct. 25, 1926
WESTERN PIPE & STEEL CO., OF CALIF. 444 Market St., San Francisco, Calif.	Aug. 13, 1924
WESTERN WELL WORKS, INC. 522 West Santa Clara St., San Jose, Calif.	Aug. 8, 1927
WITT STEEL CO. Greensburg, Pa	June 17, 1926
WOOD, R. D. & Co 400 Chestnut St., Philadelphia, Pa.	Apr. 16, 1884
WORTHINGTON PUMP & MACH'Y CORP. 115 Broadway, New York, N Y.	June 18, 1901

GEOGRAPHICAL DISTRIBUTION

ALABAMA

Active 16; Corporate 2; Associate 3; Total 21

ACTIVE

Alexander City: Robinson
Birmingham: Carson, Decker, Horner, McWane, Polglaze, Sample, Sweet, Totten, Van den Berg, Jr.
Mobile: Soost
Montgomery: Hazlehurst
Muscle Shoals: Mickel
Talladega: Dougherty
Tuscaloosa: Abbott, Moulton

CORPORATE

Birmingham: Alabama Power Co.
Guntersville: Guntersville Water Works

ASSOCIATE

Birmingham: American Cast Iron Pipe Co., McWane Cast Iron Pipe Co., National Cast Iron Pipe Co.

ARIZONA

Active 5; Corporate 1; Total 6

ACTIVE

Ajo: DuMoulin
Flagstaff: Marshall
Prescott: Shaw
Tucson: Rider, Whitacre

CORPORATE

Bisbee: Bisbee-Naco Water Co.

ARKANSAS

Active 3; Corporate 3, Total 6

ACTIVE

Fort Smith: Vaughn, Ward
Jonesboro: Christy

CORPORATE

Helena: Arkansas Utilities Co.
Hot Springs: Hot Springs Water Co.
Pine Bluff: Arkansas Power & Light Co.

CALIFORNIA

Honorary 1; Active 162; Corporate 19; Associate 35; Total 217

HONORARY

Los Angeles: Mulholland

ACTIVE

Albany: DeCosta
Alhambra: Downer, Goble
Arcadia: Lee
Bakersfield: Dillon
Berkeley: Gerhart, Hyde, Langlier, Moullet, Reinke, Rhodes, Stava
Burlingame: Henderson, Schuck
Calexico: Perhab
Campbell: Hyde
Carlsbad: Fraser
Chico: Simpson
Compton: Parrish
Corona: Case
Fresno: Barnum, Chisholm, Jackson, Leovitt, Suters
Gardena: Sevier
Glendora: Warren
Hanford: Isaac, Johns
Hayward: Smalley
Huntington Park: Mohr
Inglewood: Farmer
La Habra: Launer
Lindsay: Trauger
Los Angeles: Anderson, Barnard, Beeson, Bowen, Brooks, Cates, Chamberlain, Derby, Dodge, Finkle, Goudey, Hurlbut, Koster, Lawton, Luippold, Moore, Nicholson, Palmer, Reed, Rowe, Slater, Smith, Stone, Tarr, Taylor, Volk
Los Banos: Delaney
Manteca: Jones
Martinez: Gaul
Marysville: Belcher
Merced: Casad
Monrovia: Gierlich, Given
Monterey Park: Oberholtzer
National City: Rice
Newport Beach: Cundiff, Daley
Oakland: Davis, Farrell, Gillespie, Hawley, Hunter, Klaus, Magerstadt, Reinhardt, Stewart, Wilhelm

Ontario: Roen
Orland: Wright
Oroville: Davis
Pacific Grove: Olmstead
Palos Verdes Estates: Brownell
Pasadena: Allin, Jones, Morris
Redding: Steinhauer
Redondo Beach: Tomlinson
Sacramento: Prugh, Stevenson
St. Helena: Gertsen
Salinas: Snell
San Bernardino: Starke
San Bruno: Jorgensen
San Diego: Albin, Cowles, Ervast, Lovell, Symons, Wueste
San Francisco: Abbott, Andrews, Badger, Barker, Bovard, Bragg, Clemens, DeMartini, Elliott, Ellis, Flaa, Hammerly, Harris, Hommon, Hunter, Kempkey, Lee, Loveland, MacKall, Martindale, McCarty, O'Shaughnessy, Porter, Pracy, Randlett, Schuyler, Sharon
San Gabriel: Kline
San Jose: Ford, Green, Kittredge, Relph
San Rafael: Burt, Everette, Longland, Peters
Santa Barbara: Trace, Wyant
Santa Clara: Dixon
Santa Cruz: Tait
Santa Monica: Elrod, Vicini
Santa Paula: Giacomazzi
Sonoma: Emparan
South Pasadena: Mudge
Stanford University: Marx
Stockton: Brown, Griffin
Turlock: Brown
Tustin: Wray
Vacaville: McBride
Ventura: Orton
Verdugo City: Rider
Vernon: McCurdy
Watsonville: Kitchen
Whittier: McLaren
Willets: Morris
Willows: Snedeker
Yreka: Thomas

CORPORATE

Antioch: City of Antioch
Beverly Hills: Water Department
Burbank: Public Service Department
Glendale: Public Service Department
Los Angeles: Bureau of Water Works and Supply, Conservative Water Co., Los Angeles Water Service Co.
Madera: Municipal Water Works
Mill Valley: H. C. Symonds
National City: Sweetwater Water Co.
Oakland: East Bay Water Co.
Pasadena: Water Department
Riverside: Water Department
San Francisco: Benicia Water Co.
San Jose: San Jose Water Co.
San Mateo: Peninsula Water Co.
Santa Monica: Water Department
Vallejo: Water Department
Whittier: Water Department

ASSOCIATE

Berkeley: Steel Tank & Pipe of Calif.
Huntington Park: Pacific Pump Works.
Lankershim: Waterproof Paint Co.
Long Beach: The Rick Co.
Los Angeles: American Seamless Tube Corp. of Calif., Baker Iron Works, Calif. Meter Co., Everlasting Paint & Sales Co., James Jones Co., Frank J. Kimball Co., Los Angeles Valve & Fittings Co., Philbrook Spring Pipe Clamp Co., Rich Steel Products Co., C. W. Sirch, C. C. Sixbey, R. W. Sparling, United Casting Co., Western Concrete Pipe Co.
Oakland: Forni Manufacturing Co.
Pasadena: Art Concrete Works
Pomona: The Pomona Mfg. Co.
San Diego: Machinery Pipe & Supply Co., National Iron Works
San Francisco: Bunker Hill Smelter & North West Lead Co., Cement Gun Construction Co., M. Greenberg's Sons, Hill, Hubbell & Co., Montague Pipe & Steel Co., Street Lighting & Equipment Co., Western Pipe & Steel Co. of Calif.
San Jose: Western Well Works, Inc.
Stockton: Sterling Pump Works, Inc.
Vallejo: Rex Tapping Machine Co.
West Berkeley: Byron Jackson Pump Mfg. Co., California Corrugated Culvert Co.

COLORADO

Active 24; Corporate 7; Associate 3; Total 34

ACTIVE

Boulder: Poe
Brighton: Petersen
Colorado Springs: McReynolds, Truman
Denver: Eppich, Gross, Kepner, Leahy, Lowther, Mars, Jr.,

McLaughlin, Ristine, Jr., Robinson, Sumner, Vail, Warner, Wilson
Gunnison: Keenan
Hugo: Van Arsdale
Leadville: Sharp
Montrose: Smith
Pueblo: Porter, Stone
Rocky Ford: Strouse

CORPORATE

Boulder: Water Department
Canon City: Water Department
Fort Collins: City of Fort Collins
Grand Junction: Water Dept.
Greeley: City of Greeley
La Junta: City of La Junta
Loveland: City of Loveland

ASSOCIATE

Denver: Colorado Fuel & Iron Co., The R. Hardesty Manufacturing Co., Hendrie & Bolthoff Manufacturing & Supply Co.

CONNECTICUT

Active 21; Corporate 3; Associate 2; Total 26

ACTIVE

Ansonia: Davis
Bridgeport: Blatz, Senior
Bristol: Lourie
Danbury: Raymond
East Hartford: Walsh
Greenwich: Willson
Hartford: Berry, Newlands, Peck, Saville, Scott
New Haven: Gaillard, Glynne, Hill, Minor, Winslow
Southington: MacKenzie
Stamford: Ketcham
Thompsonville: Schwabe
Torrington: Travis

CORPORATE

Derby: Birmingham Water Co.
Hartford: State Department of Health
Middletown: Middletown Water Works

ASSOCIATE

South Norwalk: The R. U. V. Co.
Waterbury: The American Brass Co.

DELAWARE

Active 7; Total 7

ACTIVE

Dover: Beckett
Wilmington: Butz, Sr., Draper, Feeney, Hoopes, Jr., Van Trump, Wills

DISTRICT OF COLUMBIA

Active 11; Total 11

ACTIVE

Washington: Burt, Collins, Curtis, Dorsey, Hardy, Howell, Kay, Lauter, Macqueen, Thompson, Van Doren

FLORIDA

Active 50; Total 50

ACTIVE

Clearwater: Schwabel
Daytona: Graham, Main
Daytona Beach: Richards, Tippins
Fort Lauderdale: Keis, Solomon
Fort Pierce: Larmon, Smith
Gainesville: Brown
Hollywood: Jones, Stewart
Homestead: Davis
Jacksonville: Eastwood, Filby, Kolb, Parker, Simons, Jr., Tyler, Wechter
Lake Worth: Wright
Miami: Hyman, Murray
Mulberry: Madison
Opa Locka: Rowe, Russell
Orlando: Michaels, Norris, Rhynus
Palmetto: Mixson
St. Augustine: Center, Gray, Masters
St. Petersburg: Gager, Hole, Lane
Sanford: Duane
Stuart: DeMoya
Tampa: Humphreys, Jones, McFarland, Squires
Vero Beach: Damerow
West Palm Beach: Chinn, Dougherty, Mar, Reynolds, Rice, Robinson
Winter Park: Georgia

GEORGIA

Honorary 1; Active 19; Corporate 2; Associate 1; Total 23

HONORARY

Atlanta: Clayton

ACTIVE

Atlanta: Grimes, Hall, Kite, May, Neville, Rapp, Singleton, Smith, Titshaw, Wiedeman, Wilcox
Augusta: Hunter, Smith
Columbus: Darrow, Smalshaf
Newnan: Passolt
Savannah: Valentino
Thomasville: Pringle
Valdosta: Saurbrey

CORPORATE

Griffin: Light, Water & Sewerage Department
West Point: Lanett Cotton Mill

ASSOCIATE

Rome: Griffin Foundry & Manufacturing Co.

IDAHO

Active 4; Corporate 1; Total 5

ACTIVE

Boise: Turner
Idaho Falls: Wilson
Lewiston: Harris, Hughes

CORPORATE

Boise: Idaho Surveying & Rating Bureau

ILLINOIS

Honorary 2; Active 147; Corporate 9; Associate 27; Total 185

HONORARY

Chicago: Keeler
Quincy: Bull

ACTIVE

Alton: Miller
Aurora: Barclay, Dean, Willett
Bloomington: Woltman
Blue Island: Hammond
Cairo: Roos
Carbondale: Dyhrkopp
Champaign: Amsbary, Gallaher
Chicago: Allen, Alvord, Arnold, Bachmann, Bauereisen, Baylis, Berhman, Bemis, Birdsall, Burdick, Christman, Cole, Coughlan, Darby, Davidson, DeBerard, DeLeuw, Eddy, Enander, Engel, Fager, Fink, French, Gayton, Gerstein, Goldsmith, Goodman, Gordon, Gorman, Greeley, Green, Greer, Groner, Hancock, Hanley, Hansen, Harris, Hendricks, Hickox, Holmes, Holway, Horne, Horstmann, Jordan, Kivell, Knowles, McClenahan, Marner, Marshall, Massey, Matteson, Maury, Maxwell, Mendelsohn, Merckel, Mohlman, Moseley, Munn, Noble, Norton, Olson, Parsons, Pearse, Prindle, Putnam, Ramey, Rathbun, Raynolds, Rossiter, Ruchhoft, Schmid, Jr., Shaw, Sherman, Shields, Skinner, Speer, Jr., Stanley, Tanner, Thorne, Versulius, Vogelback, Wolfe
Danville: Ely, Symons
Decatur: Carrick, Hatfield, Greenfield, Warren
Des Plaines: Wells
Dixon: Hawley
East St. Louis: Horner
Elgin: Bowers
Elmhurst: Crockett
Evanston: Polk
Freeport: Hutchins
Galva: Lundberg
Harvey: Rossman
Hillview: Stoldt
Hinsdale: Menold
Jacksonville: Swanson
Kankakee: Huse
LaGrange: Howson
Mattoon: Clark, Millan, Rue
Maywood: Warnecke
Moline: Jahns
Monmouth: Boruff
Morrison: Green
Mt. Carmel: Barnhard
Murphysboro: Farrar
Newton: Holt
Oak Park: Meyers
Pana: Stanfield
Pekin: Lautz
Peoria: Baker, Crozier, Morgan, Ringness
Quincy: Gelston
Rock Island: Etzel, Murrin
Springfield: Ferguson, Reid, Spaulding
Sterling: MacDonald
Streator: Huggans
Taylorville: Dappert
Urbana: Babbitt, Buswell, Enger, Fleming, Habermeyer, Mavis, Talbot

Waukegan: Miller
Wheaton: Stickney

CORPORATE

Canton: Canton Water Works
Chicago: Illinois Inspection Bureau, Municipal Water Co. of Illinois
Lake Forest: Water Department
Moline: Water Department
Peoria: Peoria Water Works Co.
Quincy: Water Works Commission
Springfield: Central Illinois Public Service Co.
Winnetka: Village of Winnetka

ASSOCIATE

Alton: Mississippi Lime & Material Co.
Aurora: The American Well Works, Barber-Greene Co.
Chicago: Aluminate Sales Corp., American Steel & Wire Co., Automatic Cone Valve Co., Automatic Primer Co., Birch Manufacturing Co., Chicago Bridge & Iron Works, Chicago Chemical Co., J. B. Clow & Sons, Crane Co., Dearborn Chemical Co., Engineering & Contracting, Fairbanks, Morse & Co., General Chemical Co., International Filter Co., Mabbs Hydraulic Packing Co., Jos. E. Nelson & Sons, Portland Cement Association, Republic Flow Meters Co., Sullivan Machinery Co., United States Silica Co.
Decatur: Mueller Co.
Mattoon: H. W. Clark Co.
Quincy: Dayton-Dowd Co., Modern Iron Works

INDIANA

Honorary 1; Active 52; Corporate 3; Associate 3; Total 59

HONORARY

Terre Haute: Gwinn

ACTIVE

Columbus: Harger
Elkhart: Stephenson
Elwood: Barnes
Evansville: Streithof
Fort Wayne: Lennon, Waldrop
Frankfort: Marvin
Gary: Luscombe
Greencastle: Reeves
Greenfield: Wolfe
Hammond: Crane, Partridge, Schonert
Indianapolis: Brossman, Calvert, Cruger, Diggs, Garman, Hurd, Jeup (Bernard H.), Jeup (B. J. T.), Jordan (Frank C.), Jordan (Harry E.), Mabee, Mauch, Moore, Morse, Newcomer, Payes, Schwier, Winkle
Kokomo: Stradling
La Porte: Foutz
Marion: Van Cleave
Mt. Vernon: Ploch
Muncie: Stewart
Newcastle: Younce
Princeton: Gaton, Joplin
Richmond: Dill
Seymour: Peter
South Bend: Dish, McCaffery, Toyne
Sullivan: Kerlin
Terre Haute: Durbin
Valparaiso: Agar, Bradley
Vincennes: Watts
Wabash: Klare
Washington: Jones
Whiting: Bartuska

CORPORATE

Evansville: Water Works
Indianapolis: Water & Sewage Department
New Albany: Interstate Public Service Co.

ASSOCIATE

Elkhart: Moore Brothers
Lawrenceburg: A. D. Cook, Inc.
Wabash: Fort Meter Box Co.

IOWA

Honorary 1; Active 48; Corporate 3; Associate 4; Total 56

HONORARY

Davenport: Donahue

ACTIVE

Ames: Buchanan, Jenks, Levine, Murphy
Bettendorf: Schneider
Boone: Nelson
Burlington: Lawlor
Cedar Rapids: Bates, Blomquist
Centerville: Alexander
Clarinda: Ehrhart
Clinton: Chase

Council Bluffs: Etnyre, Hansen, Jensen, Myrtue
Davenport: Healey, Henderson
Des Moines: Conrath, Corcoran, Denman, Higgins, Maffitt (Dale L.), Maffitt (Howard C.), Tenny, Thorpe, Wieters
Fort Dodge: Bird, Pray
Harlan: Cox
Iowa City: Bartow, Hinman, Jr., Hostetler, Keller, Waterman
Marion: Toms
Marshalltown: Pederson
Mason City: Crofoot
Muscatine: Molis
Oskaloosa: Hawkins
Ottumwa: Brown
Sioux City: Carlin, Gaynor, Smith, Sutherland
Waterloo: Hendry, Shoemaker
Webster City: Currie

CORPORATE

Creston: Taxpayers Municipal Water Works
Dubuque: Dubuque City Water Works
Muscatine: Water Trustees

ASSOCIATE

Burlington: Murray Iron Works Co.
Council Bluffs: Giant Manufacturing Co.
Muscatine: Northern Gravel Co.
Newton: The Parsons Co.

KANSAS

Active 12; Corporate 3; Total 15

ACTIVE

Abilene: Sutton
Atchison: Chisham
Emporia: Kunz
Eureka: Huntington
Kansas City: Barclay, Mangun
Lawrence: Boyce
Manhattan: Ulrich
Salina: Paulette
Topeka: Stewart
Wichita: Kelley
Winfield: Welfelt

CORPORATE

Emporia: Water Department
Lawrence: Engineering Department
Salina: Water Department

KENTUCKY

Active 31; Corporate 6; Associate 1; Total 38

ACTIVE

Ashland: Patton
Bowling Green: Ennis
Catlettsburg: Patton
Covington: Kingsley
Frankfort: Griffin
Georgetown: Allen
Hazard: Ihrig
Henderson: Overstreet
Lawrenceburg: Madison
Lexington: Bell, Cramer (Hugh R.), Cramer (W. S.), Gillig, Pinnell
Louisville: Chambers, Clemens, Long, Lovejoy, McGonigale, Parker, Peabody, Stover
Mayfield: Orr
Maysville: Cochran
Mt. Sterling: Blevins
Owensboro: Watson
Paducah: Burnett
Paintsville: Enzweiler
Paris: Mitchell
Richmond: Doughertv
Winchester: Attersall

CORPORATE

Ashland: Water Commission
Hopkinsville: Hopkinsville Water Co.
Louisville: State Board of Health, Kentucky Utilities Co., Louisville Water Co.
Pineville: Pineville Water Supply Co.

ASSOCIATE

Louisville: Vogt Brothers Manufacturing Co.

LOUISIANA

Honorary 1; Active 9; Corporate 2; Total 12

HONORARY

New Orleans: Earl

ACTIVE

Hammond: Mentz
New Orleans: Earl, Eastwood, Fowler, Grant, O'Neill, Porter
Shreveport: Amiss, Mayo

CORPORATE

Baton Rouge: Baton Rouge Water Works Co.

Lake Charles: Gulf States Utilities Co.

MAINE

Active 11; Corporate 1; Total 12

ACTIVE

Augusta: Campbell
Bangor: Powell
Northeast Harbor: Mullikin
Ogunquit: Phillips
Orono: Everett
Portland: Coburn, Graham, West (Geo. F.), West (Vernon F.)
Rockland: McAlary
Waterville: Thompson

CORPORATE

Waterville: Trustees Kennebec Water District

MARYLAND

Active 36; Associate 1; Total 37

ACTIVE

Annapolis: Munroe
Baltimore: Adams, Armstrong, Biser, Blohm, Di Domenico, Ellis, Flack, Goldstein, Gregory, Hopkins, Keefer, Megraw, Powell, Requardt, Strohmeyer, Walden, Warren, Whitman, Wieghardt, Wolf, Wolman
Chevy Chase: Miller
Cumberland: Fowler
Frederick: Crum
Hagerstown: Cannen, Ferguson, Heard
Hyattsville: Devilbiss, Hall, Hechmer, Morse, Shaw
Linthicum Heights: Diggs, Jr.
Riverdale: Owings
Salisbury: Dryden

ASSOCIATE

Baltimore: La Motte Chemical Products Co.

MASSACHUSETTS

Honorary 2; Active 61; Associate 10; Total 73

HONORARY

Holyoke: Tighe
Lowell: Thomas

ACTIVE

Attleboro: Snell
Boston: Barbour, Chase, Clark, Eddy, Fales, Finneran, French, Goodnough, Houser, Howard, Killam, McInnes, Marston, Sherman, Skinner, Taber, Thorndike, Wentworth (Franklin H.), Wentworth (John P.), Weston, Wheeler, Williams, Winsor
Brockton: Kingman
Brookline: Hale
Cambridge: Fair, Good, Hatch, Whipple
Chestnut Hill: Gilcreas
Concord: Robinson
Danvers: Esty
Fairhaven: Gidley
Fall River: Guiney
Framingham Centre: Macksey
Holyoke: Gear
Jamaica Plain: Hough
Lawrence: Hale
Lowell: Reynolds, Safford
Medford: Dwyer
Melrose: Emerson
Milton: Heffernan
New Bedford: Chase, Drake, Taylor
Newtonville: Burnham
Reading: Taber
Somerset: Eagan
South Boston: Tilden
Southbridge: Abbott
Springfield: Lochridge
Waban: Symonds
Ware: Merrill
Wellesley Farms: Barrier
Wellesley Hills: Adams
West Somerville: Lacount
Worcester: Batchelder, Hoy, Kiernan

ASSOCIATE

Boston: Geo. A. Caldwell Co., Edson Manufacturing Corp., Hydraulic Development Co., Stone & Webster, Inc.
Indian Orchard: Chapman Valve Manufacturing Co.
Lynn: Cement Lined Pipe Co.
Neponset: Coffin Valve Co.
South Boston: Hersey Manufacturing Co.
Wakefield: The Lead Lined Iron Pipe Co.
Worcester: Union Water Meter Co.

MICHIGAN

Active 62; Corporate 7; Associate 4; Total 73

ACTIVE

Ann Arbor: Ayres, Decker, Hoad, Holland, McNamee, Williams

Cadillac: Webb
Clawson: Cookingham
Coldwater: McQueen
Detroit: Bird, Blessed, Dow, Dunham, Ellis, Fenkell, Gerardy, Grobbel, Hardin, Hinchman, Hubbell, Lenhardt, Mayo, Morrill, Orton, Outzen, Rudd, Stephenson, Wahl, Wallace, Wyckoff
E. Lansing: Woods
Fordson: McCarthy
Grand Rapids: Billings, Hamilton, Sperry, Vogelback
Highland Park: Bolton, Hoot, Whitsit
Holland: Champion
Huntington Woods: Jones
Iron Mountain: Croll, Hartmann, Senseman
Jackson: England, Hatch
Kalamazoo: Libby, Norman
Lansing: Hackett
Ludington: Williams
Marquette: Johnston
Monroe: Weaver
Mt. Clemens: Keils
Pontiac: Monroe
Port Huron: Cascadden, Moore, Naumann, Sterosky
Rochester: Jackson
Saginaw: Eymer, Johnson
Wayne: Pakes

CORPORATE

Ann Arbor: Water Works Commission
Bay City: Water Works Department
Flint: Board of Water Commissioners
Grand Rapids: Department of Public Service
Ironwood: Water Department
Pontiac: Department of Water Supply
Saginaw: Water Department

ASSOCIATE

Detroit: Burroughs Adding Machine Co., Michigan Valve & Foundry Co.
Port Huron: Mueller Brass Co.
Traverse City: Traverse City Iron Works

MINNESOTA

Honorary 1; Active 47; Corporate 3; Associate 2; Total 53

HONORARY

St. Paul: Caulfield

ACTIVE

Austin: Todd
Chisholm: Sullivan
Crookston: Peterson
Duluth: Corine, Foster, Kelly, Reed, Wilson
Eveleth: Forristel
Fairmont: Basom
Faribault: Wilson
Fridley: Wilbur
Gilbert: Connor, Spitznagel
Hibbing: Forsberg
Lake City: Howe
Lakewood: Seligman
Minneapolis: Bass, Beal, Elsberg, Finch, Janzig, Jensen, Johnson, Lundell, McCulloh, Mellen, Moberg, Raab, Schmidt, Whittaker, Woodward, Young
Proctor: Ellefson
Rochester: Schwarz
St. Cloud: Seibert
St. Paul: Crowley, Druar, Feist, Grime, Kelsey, McDonald, Routh, Shepard, Sudheimer, Thuma
Virginia: Pruett

CORPORATE

Minneapolis: Committee on Water Works, General Inspection Bureau
Winona: Board of Municipal Works

ASSOCIATE

St. Paul: Edward E. Johnson, Inc., Fred A. Waterous

MISSISSIPPI

Active 4; Total 4

ACTIVE

Jackson: Fewell
Meridian: Slaughter
Vicksburg: Worrell
Winona: Johnson

MISSOURI

Active 57; Corporate 3; Associate 1; Total 61

ACTIVE

Hannibal: Wolfe
Independence: Gallagher
Jefferson City: Helmreich, Johnson
Kansas City: Archer, Bacharach, Baldwin, Benham, Black, Foreman, Gilkison, Haskins, Holbrook, Kiersted, Jr., Learned, McCall, McDonnell, Maitland, Mullergren, Paulette, Pratt, Reynolds, Strang, Veatch, Jr., Wesley, Whitmire

St. Joseph: Bodkin
St. Louis: Allgeyer, Black, Chivvis, Cutts, Day, Easterday, Ebeler, Flad, Fleming, Fuller, Graf, Henby, Jutz, Meyer, Monfort, Nelson, Nolte, Pritchard, Richardson, Serkes, Skinker, Smith, Steinbruegge, Wall, Wilcox
Sedalia: Andrews
Springfield: Gray, Pate
University City: Weir
West Plains: Britain

CORPORATE

Kansas City: Director of the Water Department, Kansas City Power & Light Co.
St. Louis: Illinois Power & Light Corp.

ASSOCIATE

St. Louis: American Foundry & Manufacturing Co.

MONTANA

Active 28; Corporate 2; Total 30

ACTIVE

Billings: Willett
Butte: Carroll, Plummer, Probst, Thomas
Chinook: Brandis
Choteau: Hall
Columbus: McClure
Deer Lodge: Coleman
Dillon: Holtz
Glendive: Hurdle
Hardin: French
Havre: Sandquist
Helena: Foote, Nimmo
Kalispell: Lawrence, MacDonald
Laurel: Rigney
Lewistown: Schmit
Livingston: Cortese
Miles City: Becraft
Missoula: Christensen, Thane
Ronan: Odiet
Roundup: Quinnell
Superior: Horning
Troy: Hubbard
Whitefish: Bayha

CORPORATE

Anaconda: Water Works Department
Great Falls: Water Department

NEBRASKA

Active 10; Corporate 2; Associate 2; Total 14

ACTIVE

Lincoln: Erickson, Letton
Omaha: Armstrong, Barr, Bruce, Knouse, Leisen, Martin
Plattsmouth: Minor
Wilber: Diller

CORPORATE

Lincoln: Water and Lighting Department
Omaha: Metropolitan Utilities District

ASSOCIATE

Grand Island: Kelly Well Co.
Omaha: Interstate Machinery & Supply Co.

NEVADA

Active 4; Corporate 1; Total 5

ACTIVE

East Ely: Smith
Goldfield: Detwiler
Reno: Campbell
Tonopah: McGee

CORPORATE

Reno: The Truckee River Power Co.

NEW HAMPSHIRE

Active 3; Corporate 1; Total 4

ACTIVE

Concord: Howard, Storrs
Hanover: Marsden

CORPORATE

Nashua: Pennichuck Water Works

NEW JERSEY

Active 121; Corporate 11; Associate 11; Total 143

ACTIVE

Ampere: Holway, Longley
Arlington: Donnelly
Asbury Park: Bartley, White
Atlantic City: Van Gilder, Wigley
Bernardsville: Williamson
Bloomfield: Rawson
Bogota: Cowles
Boonton: Breitzke, Mallalieu
Bound Brook: Brush, Downes, Smith
Burlington: Buzby, Capron, Conard, Russell
Camden: Long, Smith, Vosbury
Cedar Grove: Goslau
Charlotteburg: Reilly
Clifton: Mahoney

Collingswood: Borden
East Orange: Halpin, Roper, Snyder
Elizabeth: Booth, Buck, Faitoute, Radcliffe, Townley
Franklin: Jenkins
Glen Ridge: Brooks
Glen Rock: Towle
Haledon: Kapp, Jr.
Harrison: Matte
Haskell: Holdredge
Hoboken: Anderson
Jersey City: Cleflin, Corbin, McEvoy, Mauzy, Tator, Van Keuren
Kearny: Campbell
Linden: Mitchell
Little Falls: Green
Lodi: McClellan
Long Branch: Herr
Merchantville: Rudderow
Millville: Buell
Montclair: Folwell, Knox
Morristown: Hoffman
New Brunswick: Atkinson, Lendall, Morris
New Milford: Cowles, Spalding
Newark: Baldwin, Bank, Ely, Foulks, Judson, Mueller, Orchard, Pratt (Arthur H.), Pratt (Gilbert H.), Rosentreter, Scherer, Scholz, Sherman, Sherrerd, Woolley
Nutley: Cutler
Orange: Luthy
Passaic: Hopper, Knight,
Paterson: Cook, Cuddeback, Edwards, Harder, King, Ryle
Perth Amboy: Mason
Plainfield: Gavett
Pleasantville: Brewer, Trumbore
Princeton: Eldridge
Rahway: Gibbons
Red Bank: Cadman, Keckler
Ridgewood: Carr
Riverside: Port
Riverton: Buck
Short Hills: Kohout
South Orange: Nolan, Smith
Summit: Bassett
Sussex: Quince
Tenafly: Howes
Trenton: Brooks, Budd, Bugbee, Croft
Upper Montclair: Wilson
Weehawken: Alfke, Davies, French, Fricker, Lebold, Miller, Schlicht, Talbot
West Orange: Fritz, Glannan
Wildwood: Banks
Woodbridge: Mundy

CORPORATE

Camden: New Jersey Water Co.
Dover: Water Commissioners
East Orange: Board of Water Commissioners
Glen Ridge: Water Department
Millville: Millville Water Co.
Montclair: Bureau of Water Supply
Mount Holly: The Mount Holly Water Co.
Newark: New Jersey District Water Supply Commission
Totowa: Borough of Totowa
Trenton: New Jersey Department Conservation and Development, Trenton Water Works

ASSOCIATE

Ampere: Lock Joint Pipe Co.
Bayonne: The Babcock & Wilcox Co.
Clayton: Hungerford & Terry, Inc.
East Orange: The Federal Meter Corp., The A. P. Smith Manufacturing Co.
Jersey City: Voorhees Rubber Manufacturing Co.
Newark: Gamon Meter Co., Wallace & Tiernan Co., Inc.
Paterson: American Zeolite Corp.
Pleasantville: Van Gilder Water Meter Co.
Trenton: DeLaval Steam Turbine Co.

NEW MEXICO

Active 2; Corporate 3; Total 5

ACTIVE

Cimarron: Alpers
Santa Fe: Fox

CORPORATE

Deming: Water Department
East Las Vegas: Agua Pura Co.
Santa Fe: New Mexico Power Co.

NEW YORK

Honorary 3; Active 300; Corporate 29; Associate 57; Total 389

HONORARY

New York: Herschel, Smith
Troy: Mason

ACTIVE

Albany: Bates, Cook, Cox, Holmquist, Horton, Prior, Slack, Suter Wachter, Wheeler, Willcomb
Amsterdam: Dwyer
Astoria: Culyer
Avon: Clark
Babylon: Clark
Binghampton: Gitchell

Briarcliff Manor: Manahan
Bronxville: Stearns
Brooklyn: Aeryns, Armstrong, Bleistein, Cunningham, Dowd, Flannery, Gaffney, Hale, Hendrick, Lott, Metcalf, Woolnough, Vertefeuille
Buffalo: Ames, Andrews, Ballard, Bartram, Bassett (Charles K.), Bassett (Geo. B.), Boyle, Chambers, Diehl, Fitzgerald, Grotz, Huy, Lautz, Nussbaumer, Parsons, Reisweber, Roberts, Showell, Jr., Spire, Wagner
Canandaigua: Ellis
Corning: Drake
Cortland: Eginton, Peck
Croton-on-Hudson: Barnes
Dunkirk: Peck
East Rochester: Babcock
Elmira: Jones
Elsmere: Bedell, Tiedeman
Fairport: Scarth
Far Rockaway: Bettes, Durland, Stearns
Flushing: Laase
Geneseo: Meeker
Gloversville: Orr
Grand Gorge: Honness
Haverstraw: Chapman
Hempstead: Marshall, Stevens
Herkimer: Wood
Highbridge: Nelson
Highland: Schantz
Hudson Falls: Fasoli
Ilion: Trimble
Ithaca: Chamot, Seery
Jackson Heights: Craig
Jamestown: Swanson
Katonah: Coffin
Kenmore: Evans
Kingston: Harrison, Loughran
Larchmont: Foote, Hoffmaster
Le Roy: Palmer
Little Falls: Feeter
Long Island City: Ankener, Weaver
Lynbrook: Clark
Lyons: Zimmerlin
Malone: Van Deusen
Mamaroneck: Duffy, Nordmann
Manhasset: Hoag
Marion: Howell
Medina: Phillips
Merrick: Spear
Middletown: Korschen, LaPolt
Mineola: Bowne
Mount Kiso: Sawin
Mount Vernon: Havill, Wolbert
Newark: Wright
Newburgh: Gilcrist
New Rochelle: Applebaum, Cranch, Kemble, Lloyd, Reynolds, Jr., Wilson
New York: Baker, Baldwin, Ballou, Bannister, Barnes, Barns, Berry, Besselievre, Beyer, Biggs, Jr., Blanchard, Blossom, Bogert, Booth, Bowe, Brush, Bull (Charles H.), Bull (Irving C.), Case, Chase, Chenery, Cleveland, Cleverdon, Clowes, Cole, Coulter, Cunningham, Dennett, Dodd, Donaldson, Duggan, Dunham, Enslow, Everett, Ewry, Ferguson, Flinn, Freer, Fuertes, Fuller, Geehan, Gordon, Gould, Hansen, Harding, Harding, Jr., Hazen, Hill, Jr., Hoag, Hoagland, Hodgman, Hogan, Howland, Hutson, Jackson, Jacobs, Jacobsen, Johnson, Jones, Kenzle, Kienle, Klein, Kneen, Kriegsheim, Ledden, Luce, McClintock, McKay, Manahan, Merriman, Meyerherm, Milholland, Newsom, Niesley, Nuebling, O'Connor, O'Leary, Ortiz, Patitz, Pease, Phelps, Phillips, Pincus, Pirnie, Potter, Potts, Provost, Jr., Rice, Sanborn, Scott, Siems, Spear, Stearns, Stewart, Sullivan, Tainter, Tribus, Tuttle, Van Gorder, Vermeule, Watt, Wells, Wiggin, Williamson, Wood
Niagara Falls: Dignan, McCulloh, Perry, Robbins, Suitor
North Tarrytown: Helling
North Tonawanda: Batt
Norwich: Ames, Riley
Oneida: White
Oneonta: Lyon, Lyon (Mrs.)
Ossining: Bedell
Oswego: McCaffrey
Peekskill: Clark, Lockwood
Perry: Snyder
Prattsville: Fifield
Rensselaer: Claflin
Rochester: Baker, Beck, Bliven (Geo. H.), Bliven (M. Harvey), Fisher, Hopkins, Kittredge, Lewis, Little, Lynch, Matthews, Miller, Prince, Russell, Skinner, Story
Rockville Centre: Cook
Scarsdale: Henshaw, Wyckoff
Schenectady: Devendorf, Erickson, Taylor
Schuylerville: Grenalch
Slingerlands: Slingerland
Southampton: Van Brunt
South Nyack: Kendall
South Ozone Park: Sleeper
Staten Island: Barnes

Syracuse: Booth, Daw, Keating, Palmer, Ridley, Starbird, Stewart, Williams, Jr.
Troy: Caird, Caldwell, Clifton, End, Knickerbacker
Utica: Allen, Dewey, Hodges, Hopkins, (Edwin W.) Hopkins, (Franklyn C.) Miles, Robertson
Valley Stream: Morlan
Voorheesville: Horton
Wappingers Falls: Beasley
Warren Point: Bishop
Waterford: Yaxley
Waterloo: Stewart
Watertown: Ackerman, Field
Wellsville: Allen, Rowe
White Plains: Mapes
Woodhaven: Bliven
Yonkers: Buhrendorf, Curran

CORPORATE

Auburn: Water Department
Babylon: Sumpwams Water Works Co.
Buffalo: Bureau of Water, Western New York Water Co.
Corning: Water Works
Elmhurst: Citizens Water Supply Co.
Elmira: Water Board
Glens Falls: Board of Water Commissioners
Ilion: Board of Water Commissioners
Johnson City: Water Department
Kenwood: Sherril-Kenwood Water Commission
Lockport: Board of Water Commissioners
Lowville: Adirondack Water Works
Maspeth: Urban Water Supply Co.
New Rochelle: The New Rochelle Water Co.
New York: American Water Works & Electric Co., Inc., Community Water Service Co., Federal Light & Traction Co., G. V. Grace & Co., Roanoke Water Works Co.
Oswego: Department of Water
Owego: Owego Water Works
Point Pleasant: Sea Breeze & Vicinity Water Commission
Poughkeepsie: Board of Public Works
Rome: Department of Public Works
Syracuse: Bureau of Water
Troy: Bureau of Water
Watertown: Water Works
White Plains: Department of Public Works

ASSOCIATE

Baldwinsville: Morris Machine Works
Brooklyn: The Electric Welding Co. of America, Joseph C. Pollard Co., Inc., Stone & Tar Products Co.
Buffalo: Buffalo Meter Co., W. P. Taylor Co., William H. Thompson & Co., Inc.
Cohoes: Cohoes Rolling Mill Co.
Elmira: The Kennedy Valve Manufacturing Co.
Newburgh: Coldwell-Wilcox Co.
New York: Ambursen Construction Co., Inc., American City, Arnold, Hoffman & Co., Inc., Asphalto-Concrete Corp., Briggs Bituminous Composition Co., Inc., The Central Foundry Co., Copper & Brass Research Assoc., R. W. Cramer & Co., Inc., The Dorr Company, Inc., East Jersey Pipe Co., Electro Bleaching Gas Co., Engineering News-Record, The Fairbanks Co., John Fox & Co., General Office Equipment Corp., T. A. Gillespie Co., Hooker Electrochemical Co., Ingersoll, Rand Co., Kalbfleisch Corp., The Mathieson Alkali Works, Inc., National Meter Co., National Water Main Cleaning Co., Neptune Meter Co., B. Nicoll & Co., Inc., Parsons, Klapp, Brickerhoff & Douglas, The Permutit Co., The Pitometer Co., Public Works, S. E. T. Valve & Hydrant Co., The Sanitation Corp., Sims Pump Valve Co., Thomson Meter Co., United Lead Co., Victaulic Company of America, Wailes Dove-Hermiston Corp., Warren Foundry & Pipe Co., Water Works Engineering, Water Works Equipment Co., Worthington Pump & Machinery Corp.
Peekskill: The Fleischmann Co.
Schenectady: General Electric Co.
Princes Bay: Phoenix Meter Co.
Troy: W. & L. E. Gurley, Ludlow Valve Manufacturing Co., Rensselaer Valve Co., Ross Valve Manufacturing Co., Inc.
Waterford: Eddy Valve Co.

NORTH CAROLINA

Active 87; Corporate 1; Associate 1; Total 89

ACTIVE

Albemarle: Beckham, Moore
Asheville: Burchard
Badin: Lilly
Bessemer City: White
Bryson City: Welch
Cary: Heater
Chapel Hill: Baity, Ray, Jr., Saville, Worth
Charlotte: Bishop, Booker, Davis, Drane, Greenlee, Heyward, McConnell, Marshall, Mees, Myers, Norcom, Purser, Vest
Concord: Fisher
Durham: Davis, Michie, Piatt, Suggs, White, Williams
Eagle Springs: Maurice
Edenton: Lock
Farmville: McAdams
Fayetteville: Shell
Fremont: Benton
Franklinton: Cooke
Gastonia: Rhyne, Struthers
Goldsboro: Grantham
Greensboro: Boyles, Lewis, Smedberg, True
Greenville: Swartz
Guilford College: Trogdon
Henderson: Bridgers
Hendersonville: Lompley, Wright
High Point: Roach
Kings Mountain: Parsons
Lexington: Bullard
Louisburg: Hill
Lumberton: McNeil
Mebane: Michael
Mooresville: Fields
Morehead City: McCrea
Mount Airy: Absher
Mount Holly: Patterson
New Bern: Godfroy
Pinehurst: Pender
Raleigh: Bain, Brockwell, Catlett, Kellogg, McLeod, Miller, Olsen, Weir, Whitener
Reidsville: Bughes
Robersonville: Coburn
Rocky Mount: Lyon
Rutherfordton: Anderson
Salisbury: Craig
Southern Pines: Jarrett
Statesville: Cochran
Wake Forest: McKaughan
Waynesville: Logan
Weldon: Moss
Wilmington: Lassiter, Maffitt, Sweeney
Wilson: Gladding, Whitley
Winston-Salem: Ludlow
Zebulon: Finch

CORPORATE

Badin: Tallassee Power Co.

ASSOCIATE

Charlotte: The Grinnell Co., Inc.

NORTH DAKOTA

Active 3; Corporate 1; Total 4

ACTIVE

Bismarck: McRoberts, Yegen
Minot: Thomas

CORPORATE

Bismarck: Regulatory Department

OHIO

Active 91; Corporate 10; Associate 13; Total 114

ACTIVE

Akron: Barston, Hibbs, Paul, Stringfellow
Barberton: Campion
Bucyrus: Lower
California: Bahlman
Canton: McClaskey, Ohliger
Cincinnati: Evans, Hill, Jeup, Miller, Streeter, Theriault
Cleveland: Antweiler, Beardsley, Ellms, Farrell, Gascoigne, Habeshian, Havens, Jaeger, Jones (Allen A.), Jones (Frank Woodbury), Lawrence, Levy, Linders, Marshall, Perkins, Quayle, Ruggles, Schmitt, Sheal, Siedle, Tolles, Wright
Columbus: Bradbury, Burgess, Foulk, Groeniger, Hoover (Charles P.), Hoover (Clarence B.), Kimberly, Knox, Kramer, Lathrope, Laux, Lawrence, McAlpine, Martin, Pierce, Prior, Sickel, Walker, Waring
Dayton: Moorehouse, Prinz, Wight
Dennison: Romig
Kent: Gettrust
Lima: Brower, Evans
Lorain: Brown, Humason
Marion: Browne
Medina: Fretter
Middletown: Gebhart
Piqua: Montgomery
Shelby: Bricker
Steubenville: Scott
Tiffin: Wetter
Toledo: Brown, Champe, Clark, Furman, Jones, Keller, Roberts, Sawyer, Schoonmaker, Sherman
Warren: Inman, O'Connor
Washington C. H.: O'Neall

Xenia: Zell
Youngstown: Dittoe, Dixon, Kinder, Russell, Van Arnum

CORPORATE

Ashtabula: The Ashtabula Water Supply Co.
Columbus: Ohio Inspection Bureau
Marion: Columbus, Delaware & Marion Electric Co., Marion Water Co.
Massillon: Massillon Water Supply Co.
Middleport: The Meigs Water Co.
Sandusky: Filtration Plant
Struthers: Mahoning Valley Water Co.
Toronto: Board of Public Affairs
Wilmington: The Dayton Power & Light Co.

ASSOCIATE

Akron: The Biggs Boiler Works Co.
Cincinnati: Bourbon Copper & Brass Works Co.
Cleveland: The Bowler Foundry Co., The Farnan Brass Works Co., Glauber Brass Manufacturing Co., The Fred W. Hanks Co., The Ohio Varnish Co., The Parker Appliance Co.
Findlay: Buckeye Traction Ditcher Co.
Massillon: The Ohio Drilling Co., Peerless Pump Co.
Middletown: The American Rolling Mill Co.
Toledo: McCloskey Torch Co.

OKLAHOMA

Active 8; Total 8

ACTIVE

Chickasha: McBurnett
Oklahoma City: Bretz, Flentje, Rupp
Ponca City: Crow
Tulsa: Dones, Ginter, Wardle

OREGON

Active 10; Corporate 1; Total 11

ACTIVE

Hillsboro: Gates
Jefferson: Mars
Marshfield: Corey
Portland: Ehle, Helwick, Koon, Morrow, Murray, Wagner, Willard

CORPORATE

Portland: Department of Public Utilities

PENNSYLVANIA

Active 174; Corporate 20; Associate 28; Total 222

ACTIVE

Allentown: Schnabel
Altoona: Campbell
Ambler: Hibschman
Aspinwall: Drake
Beaver Falls: Burnie
Bethlehem: Shipman
Bristol: Roberts, Jr.
Brookville: Sayer
Bryn Mawr: Davis, McCurdy
Carbondale: Schroeder
Carlisle: Waggoner
Catasauqua: Muser
Chambersburg: Mowrey
Chester: Calhoun, Jenne, Lamey
Chinchilla: Salisbury
Clearfield: Hess, Nevling
Columbia: Meyers
Cooperstown: Crawford
Corry: Brown
Cynwyd: Suttle
Downingtown: Wagner
Easton: Rader
Erie: Dunwoody, Gensheimer
Ford City: Wintgens
Glenside: Goentner
Greensburg: Smith, Spencer
Harrisburg: Avery, Craig, Daniels, Gannett, Glace, Hassler, Mark, Moses, Scheffer, Stevenson, Weed (Ellsworth S.), Weed (Frederick H.)
Hazleton: McGeehin
Indiana: Lyle
Jersey Shore: Kinter
Johnstown: Crichton, Hagins, Kunkle, Watkins
Lancaster: Axe, Goodell, Ruth, Will
Langhorne: Stompler
Lansdowne: Jenkins
Lansford: Roads, Jr.
Lehighton: West
McKeesport: Trax
McKees Rocks: Beech
Meadville: Ellsworth, Siebert
Monongahela: Nutt
Natrona: Knight
New Castle: Hotchkiss
New Kensington: Griffiths
Norristown: Russell (Brinton), Russell (Cecil B.)
North East: Leet
Philadelphia: Bartlett, Bean, Becker, Blaisdell, Blew, Boardman, Corin, Davis, Diven, Jr., Dunlap, Easby, Jr., Emerson, Jr., Freeburn, Friel,

Greer, Gushee, Harder, Haydock, Landreth, Lawrence, Ledoux, Levering, McCaleb, McCrudden, Nichols, Riebel, Saunders, Schaut, Siddons, Simpson, Stein, Stone, Swaab, Thomas, Tolson, Van Loan, Walker, Welsford, Wertz, Yoder

Pittsburgh: Bankson, Baton, Brennan, Chester, Douglass, Foote, Harshbarger, Holmes, Hopkins, Hudson, Hutton, Knowles, Laboon, Lanpher, Leopold, Mansfield, Mellon, Rice (Cyrus Wm.), Rice (John M.), Simpson, Speller, Weidlein

Pottsville: Beisel, Clayton, Richards

Reading: Felix, Mast, Nuebling, O'Reilly, Reber, Reeder, Strockbine

Sayre: West, Wright

Scranton: Cox, Nebelung, Taylor

Shamokin: Haupt, McWilliams

Shenandoah: Rassier

South Williamsport: Barrick

Springdale: Griffin, Pierce

State College: Sackett, Walker

Steelton: Litch

Stroudsburg: Holbrook

Sunbury: Rohrbach

Swarthmore: Alleman, Fuller

Tyrone: Crawford

Upper Darby: Streander

Vandergrift: Horn

Washington: Morrow

Wayne: Pugh

Wilkes-Barre: Matter, Vail, Wintermute

Wilkinsburg: Fox, Hawley

Williamsport: Keliher, Wilhelm

York: Giesey, Kable

CORPORATE

Allentown: Water Department

Bethlehem: City of Bethlehem

Easton: Northampton Consolidated Water Co.

Ellwood City: Ellwood Water Co.

Emporium: Emporium Water Co.

Erie: Commissioners of Water Works

Harrisburg: Pennsylvania State Water Corp.

Lewistown: Lewistown-Reedsville Water Co.

Milton: White Deer Mountain Water Co.

Mount Carmel: Mount Carmel Water Co.

Reading: Bureau of Water

Scranton: Scranton Gas & Water Co.

Sharon: Shenango Valley Water Co.

Shenandoah: Commissioners of Water Works

Uniontown: Trotter Water Co.

Verona: The Suburban Water Co.

Washington: Citizens Water Co.

West Newton: West Newton Water Co.

Williamsport: Eagles Mere Water Co., Williamsport Water Co.

ASSOCIATE

Beaver Falls: Keystone Driller Co.

Berwick: Multiplex Manufacturing Co.

Bradford: S. R. Dresser Manufacturing Co.

Bryn Mawr: Philadelphia Suburban Water Co.

Emaus: Donaldson Iron Co.

Erie: Hays Manufacturing Co.

Greensburg: Witt Steel Co.

Philadelphia: American Water Softener Co., M. L. Bayard, E. I. duPont de Nemours & Co., Kingsbury Machine Works, Inc., The Leadite Co., Inc., The Pennsylvania Salt Manufacturing Co., Roberts Filter Manufacturing Co., Scofield Engineering Co., Simplex Valve & Meter Co., Talbot Non-Corrosive Linings Co., United States Cast Iron Pipe & Foundry Co., R. D. Wood & Co.

Pittsburgh: A. M. Byers Co., Dravo-Doyle Co., National Tube Co., Pittsburgh-Des Moines Steel Co., Pittsburgh Equitable Meter Co., Pittsburgh Testing Laboratory, Riter Conley Co.

Sharon: Penstock Construction Co.

Williamsport: The Darling Valve & Manufacturing Co.

RHODE ISLAND

Active 5; Corporate 1; Associate 1; Total 7

ACTIVE

Bristol: Jones

Providence: Bugbee, Gage, Marsh, Richardson

CORPORATE

Providence: Water Maintenance Department

ASSOCIATE

Providence: Builders Iron Foundry

SOUTH CAROLINA

Active 12; Corporate 1; Total 13

ACTIVE

Camden: Chapman
Charleston: Gibson, Parker
Columbia: Fisher, White
Easley: Rogers
Greenville: Blackwelder, Perry
Newberry: Schumpert
Spartanburg: Beebe, Simms, White

CORPORATE

Charleston: Commissioners of Public Works

SOUTH DAKOTA

Active 3; Corporate 1; Total 4

ACTIVE

Huron: Hays
Sioux Falls: Connor
Vermillion: Hunter

CORPORATE

Sioux Falls: Water Works

TENNESSEE

Active 21; Corporate 2; Associate 3; Total 26

ACTIVE

Chattanooga: Lofton, Porzelius, Swearingen
Cookeville: Collier
Covington: Charter
Dyersburg: Blakeman
Fountain City: Murphy
Greeneville: McAmis
Jackson: Baker
Kingsport: Webster
Knoxville: Mathews, Switzer
Memphis: Allen, Dean, Mantel
Murfreesboro: Lowe
Nashville: Clark, Fullerton, Harrub, Holman, Reyer

CORPORATE

Knoxville: Water Department
Memphis: Board of Water Commissioners

ASSOCIATE

Chattanooga: Columbian Iron Works
Knoxville: W. J. Savage Co.
Memphis: Layne & Bowler Co.

TEXAS

Active 25; Corporate 2; Total 27

ACTIVE

Amarillo: Nichols
Austin: Avery, Bantel, Green, Norris, Zilker
Beaumont: Bernhagen
Bonham: Whedbee
Dallas: Morey, Jr., O'Neil, Rosenthal
Fort Worth: Hawley, Mahlie, Quigley
Houston: McVea, Randolph
McAllen: Boyle
Mineral Wells: Smart
San Antonio: Bartlett, Newcomb
Waco: Bardwell, Gooch
Weatherford: Cherry
Wichita Falls: Curd, Ward

CORPORATE

Dallas: Dallas City Waterworks
Waco: Waco Water Works

UTAH

Active 3; Corporate 1; Total 4

ACTIVE

Brigham City: Roskelley
Salt Lake City: Lyman, Painter

CORPORATE

Salt Lake City: Water Department

VERMONT

Active 1; Total 1

ACTIVE

Burlington: Moat

VIRGINIA

Active 22; Corporate 3; Associate 4; Total 29

ACTIVE

Alexandria: Lambert
Charlottesville: Williamson
Covington: Barnett
Danville: Brantly
Denbigh: Bowers
Falls Church: Anderson
Fredericksburg: Houston, Jr.
Hampton: Engle
Lynchburg: Wagner
Newport News: Dugger
Norfolk: Bliven, Tarbett
Petersburg: Bunting
Portsmouth: Davis
Richmond: Baldwin, Bardwell, Clai-

borne, Messer, Rasch, Jr., Smith, Snidow
Roanoke: Moore

CORPORATE

Alexandria: Alexandria Water Co.
Hopewell: Old Dominion Water Corp.
Norton: Water Department

ASSOCIATE

Lynchburg: The Glamorgan Pipe & Foundry Co., Lynchburg Foundry Co.
Richmond: Sydnor Pump & Well Co., Inc., Virginia Machinery & Well Co., Inc.

WASHINGTON

Active 15; Corporate 1; Total 16

ACTIVE

Bremerton: Casad
Chelan: Harper
Everett: Klapp
Hoquiam: Heermans
Puyallup: Phillips
Seattle: Botten, Grant, Jacobs, Shibley
Spokane: Harding
Tacoma: Blair, Kunigk, Roberts, Stannard
Vancouver: Clarke

CORPORATE

Spokane: Water Division

WEST VIRGINIA

Active 23; Corporate 3; Associate 1; Total 27

ACTIVE

Bluefield: Rhoads
Charleston: Musser, Tisdale
Chester: Young
Clarksburg: Boynton, Highland
Elkins: Tyler
Fairmont: Morris
Huntington: Johnson, Watt
Montgomery: Burgess
Morgantown: Carpenter
Moundsville: Hetzer
Mullens: Kirby
Parkersburg: DeVaughn
St. Albans: Campbell
Shinnston: Riffee
Welch: Beavers
Weston: Blair, Jr.
Wheeling: Coffey, Rickard, Shull, Stern

CORPORATE

Charleston: West Virginia Water Service Co.
Dunbar: Dunbar Water Co.
Morgantown: West Virginia Utilities Co.

ASSOCIATE

Charleston: Raymond Equipment Co.

WISCONSIN

Active 45; Corporate 4; Associate 2; Total 51

ACTIVE

Antigo: Jackson
Appleton: Hall, Morris
Cedarburg: Schneider
Eau Claire: Brown
Fort Atkinson: Leonard
Janesville: Griffey
Kenosha: Hurtgen
Madison: Baker, Corp, Domogalla, Kirchoffer, Mead, Miller, Muegge, Peirce, Smith, Thiessen, Warrick
Manitowoc: Schroeder
Marshfield: Marvin
Menasha: Kuester
Milwaukee: Bohmann, Cunliffe, Daniel, Engh, Gruetzmacher, Hatton, Murphy, Schwada, Wright
Monroe: Schneider
Racine: Smith
Sheboygan: Donohue
Sparta: Erickson
Stoughton: Snyder
Superior: Corine, Lounsbury, Winslow
Tomah: Drow
Watertown: Reichardt
Waukeshaw: Hayford
Waupun: Barnett
Wauwatosa: Hebbring
Wisconsin Rapids: Gross

CORPORATE

Delavan: Water Commission
Fond du Lac: City Water Department
Green Bay: Water Department
Sheboygan: Board of Water Commissioners

ASSOCIATE

Milwaukee: Allis-Chalmers Manufacturing Co., Badger Meter Manufacturing Co.

WYOMING

Active 5; Total 5

ACTIVE

Casper: Fair
Gillette: Thomas
Rock Springs: Bell
Sheridan: Gwillim, MacCarty

CANADA

Active 117; Corporate 19; Associate 6; Total 142

ACTIVE

Brandon: Shaw
Brantford: Wilson
Brockville: Farquharson
Calgary: Breen
Carleton Place: Rogers
Charlottetown: McMillan
Cobourg: Skidmore
Dundas: Wright
Edmonton: Owens, Turner
Elmira: Bowman
Galt: Cowan
Hamilton: Buchanan, Darling, McFaul
Hull: Lanctot
Ingersol: Hall
Islington: MacNicol
Kitchener: Pequegnat
Lindsay: Hammond
London: Buchanan, Hodkinson
MacDonald College: Stephen
Montreal: Baudouin, Cousineau, Dorrance, Field, Gerin, Hunter, Hutchison, Jette, Lafreniere, Laurie, Lea, LeSage, Leslie, McCrady, Meadows, Montabone, Perry, Pitcher, Plamondon, Scofield, Ward
New Toronto: Thomas
Niagara Falls: Acres, Collins, Ferris, Warder
North Bay: Mackie
Orillia: Starr
Oshawa: Smith
Ottawa: Ferguson, Macallum, MacDonald, McRae (John B.), McRae (J. Percy)
Owen Sound: Pratt
Perth: Smith
Peterborough: Dobbin, Hunt
Quebec: Casgrain, Lessard, Tremblay
Regina: Farrell
St. Catharines: Milne
St. James: Pilgrim
St. Stephen: Laflin
St. Thomas: Miller, Peart
Sarnia: Hall
Shawinigan Falls: Vermette
Southend: Pringle
Stratford: Myers
Strathroy: Smithrim
Temiskaming: Grimmer
Three Rivers: Gelinas
Toronto: Allen, Angus, Austin, Berry, Chipman, Coles, Dallyn, Delaporte, Gaby, Gore, Hannan, Harris, Harrison, Heath, Howard, Jack, Proctor, Redfern, Routledge, Salmond, Sanderson, Storrie, Thompson, Benschoten, Walker, Wynne-Roberts
Vancouver: Brakenridge, Cleveland, Dowling
Victoria: Blair
Walkerville: Brown, Rolfson
Waterloo: Schiedel
Weston: Peirson
Windsor: Hanna, Keith, Kellner
Winnipeg: Hooper, Scott
Woodstock: Archibald

CORPORATE

Brampton: Water Commission
Brantford: Water Commissioners
Chatham: Board of Water Commissioners
Gananoque: Water Works Commission
Grimsby: Water Commission
Guelph: Water Department
Kitchener: Water Commission
Leamington: Corporation of Town of Leamington
London: Public Utilities Commission
Merritton: Water Works Department
Midland: Public Utilities Commission
Peterborough: Waterworks Department
Regina: Waterworks Department
St. Marys: Board of Water, Light & Heat Commission
St. Thomas: Water Commission
Sandwich: Water Board
Welland: Board of Water Commission
Whitby: The Public Utility Commission
Windsor: The Water Commissioners

ASSOCIATE

Montreal: Francis Hankin & Co. Ltd., Jenkins Bros., Ltd.
Toronto: The Canadian Engineer, Drummond, McCall & Co., Ltd., Hugh C. MacLean Publications, Ltd., National Iron Corp., Ltd.

FOREIGN (Except Canada)

Honorary, 1; Active, 78; Corporate, 6; Total 85.

HONORARY

ENGLAND

London: Houston

ACTIVE

ARGENTINE REPUBLIC

Buenos Aires: Bado, Berrino, Lasso, Negri, Paitovi, Soler
Mendoza: Ivanissevich
Rosario de Santa Fe: Buchanan, Gache, Moir
San Nicholas: Hudson

AUSTRALIA

Brisbane: Peart
Melbourne: Hughes, Hume, Ritchie, Sutherland
Mt. Charlton, Queensland: Symonds
Newcastle: Ewing
Perth: Haywood
Sydney: Blain

BRAZIL

Rio de Janeiro: De Brito

CANAL ZONE

Ancon: Bunker, Hatch
Cristobal: Dunn
Gatun: Beers, Jr.

CHILE

Santiago: Lira, Stalbird

CHINA

Shanghai: Gaunt, Michau, Pearson
Tientsin: Clark, Lilly

COLOMBIA

Bogota: Tanco
Medellin: Wilson

CUBA

Havana: Cosculluela, Montoulieu

DENMARK

Copenhagen: Jarvis

ENGLAND

Birmingham: Dixon
Bradford: Mitchell
Buxton: Race
Coventry: Morgan
Dewsbury: Holdsworth
London: Cameron, Howland, McIntosh, Paterson
Manchester: Hill
Newport: Spencer
Northwich: Munro

FRANCE

Nancy: Paul
Paris: Dienert, Pain

GERMANY

Breslau: Meinecke
Dresden: Vollmar

GREECE

Athens: Gausmann, Merriman

HAWAII

Honolulu: Doten, Tay, Wall

HOLLAND

Utrecht: Massink, Meerburg

HUNGARY

Budapest: Vojcsik

INDIA

Calcutta: Walker
Gwalior: Prokofieff

ITALY

Brescia: Franchi
Firenze: De Horatiis

JAPAN

Osaka: Sawai
Tokyo: Inoue, Iwasaki, Kayanoki, Nishioeda

MEXICO

Torreon: Robles

PHILIPPINES

Manila: Gideon

POLAND

Warsaw: Geupel

SANTO DOMINGO

Santo Domingo: Adams

SCOTLAND

Ayr: Ball

STRAITS SETTLEMENTS

Singapore: Tomlinson

SWEDEN

Stockholm: Greyerz

CORPORATE

AUSTRALIA

Sydney: Metropolitan Board of Water Supply & Sewerage

CUBA

Havana: Negociado de Acueductosy Alcantarillado

HAWAII

Honolulu: Dept. of Public Works
Oahu: Wahiawa Water Co., Ltd.

HOLLAND

Utrecht: Utrechtsche Waterleiding-Maatschappij

SWEDEN

Malmo: Malmo Byggnadskontor

SUMMARY BY STATES

	Active	*Corporate*	*Associate*	*Honorary*	*Total*
Alabama	16	2	3		21
Arizona	5	1			6
Arkansas	3	3			6
California	162	19	35	1	217
Colorado	24	7	3		34
Connecticut	21	3	2		26
Delaware	7				7
Dist. of Col	11				11
Florida	50				50
Georgia	19	2	1	1	23
Idaho	4	1			5
Illinois	147	9	27	2	185
Indiana	52	3	3	1	59
Iowa	48	3	4	1	56
Kansas	12	3			15
Kentucky	31	6	1		38
Louisiana	9	2		1	12
Maine	11	1			12
Maryland	36		1		37
Massachusetts	61		10	2	73
Michigan	62	7	4		73
Minnesota	47	3	2	1	53
Mississippi	4				4
Missouri	57	3	1		61
Montana	28	2			30
Nebraska	10	2	2		14
Nevada	4	1			5
New Hampshire	3	1			4
New Jersey	121	11	11		143
New Mexico	2	3			5
New York	300	29	57	3	389
North Carolina	87	1	1		89
North Dakota	3	1			4
Ohio	91	10	13		114
Oklahoma	8				8
Oregon	10	1			11
Pennsylvania	174	20	28		222
Rhode Island	5	1	1		7
South Carolina	12	1			13
South Dakota	3	1			4
Tennessee	21	2	3		26
Texas	25	2			27
Utah	3	1			4
Vermont	1				1
Virginia	22	3	4		29
Washington	15	1			16
West Virginia	23	3	1		27
Wisconsin	45	4	2		51
Wyoming	5				5
Canada	117	19	6		142
Foreign (except Canada)	78	6		1	85
October 1, 1927	2115	204	226	14	2559
October 1, 1926	2031	190	205	15	2441
Gain in year	84	14	21	—1	118